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Ecosystems and Human Well-being: Multiscale Assessments, Volume 4

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Ecosystems and Human Well-being: Multiscale Assessments, Volume 4

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Findings of the Sub-global Assessments Working Group
of the Millennium Ecosystem Assessment

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Millennium Ecosystem Assessment: Objectives, Focus, and Approach

The Millennium Ecosystem Assessment was carried out between 2001 and 2005 to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being. The MA responds to government requests for information received through four international conventions—the Convention on Biological Diversity, the United Nations Convention to Combat Desertification, the Ramsar Convention on Wetlands, and the Convention on Migratory Species—and is designed to also meet needs of other stakeholders, including the business community, the health sector, nongovernmental organizations, and indigenous peoples. The sub-global assessments also aimed to meet the needs of users in the regions where they were undertaken.

The assessment focuses on the linkages between ecosystems and human well-being and, in particular, on "ecosystem services." An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. The MA deals with the full range of ecosystems—from those relatively undisturbed, such as natural forests, to landscapes with mixed patterns of human use and to ecosystems intensively managed and modified by humans, such as agricultural land and urban areas. Ecosystem services are the benefits people obtain from ecosystems. These include *provisioning services* such as food, water, timber, and fiber; *regulating services* that affect climate, floods, disease, wastes, and water quality; *cultural services* that provide recreational, aesthetic, and spiritual benefits; and *supporting services* such as soil formation, photosynthesis, and nutrient cycling. The human species, while buffered against environmental changes by culture and technology, is fundamentally dependent on the flow of ecosystem services.

The MA examines how changes in ecosystem services influence human well-being. Human well-being is assumed to have multiple constituents, including the *basic material for a good life*, such as secure and adequate livelihoods, enough food at all times, shelter, clothing, and access to goods; *health,* including feeling well and having a healthy physical environment, such as clean air and access to clean water; *good social relations,* including social cohesion, mutual respect, and the ability to help others and provide for children; *security,* including secure access to natural and other resources, personal safety, and security from natural and human-made disasters; and *freedom of choice and action,* including the opportunity to achieve what an individual values doing and being. Freedom of choice and action is influenced by other constituents of well-being (as well as by other factors, notably education) and is also a precondition for achieving other components of well-being, particularly with respect to equity and fairness.

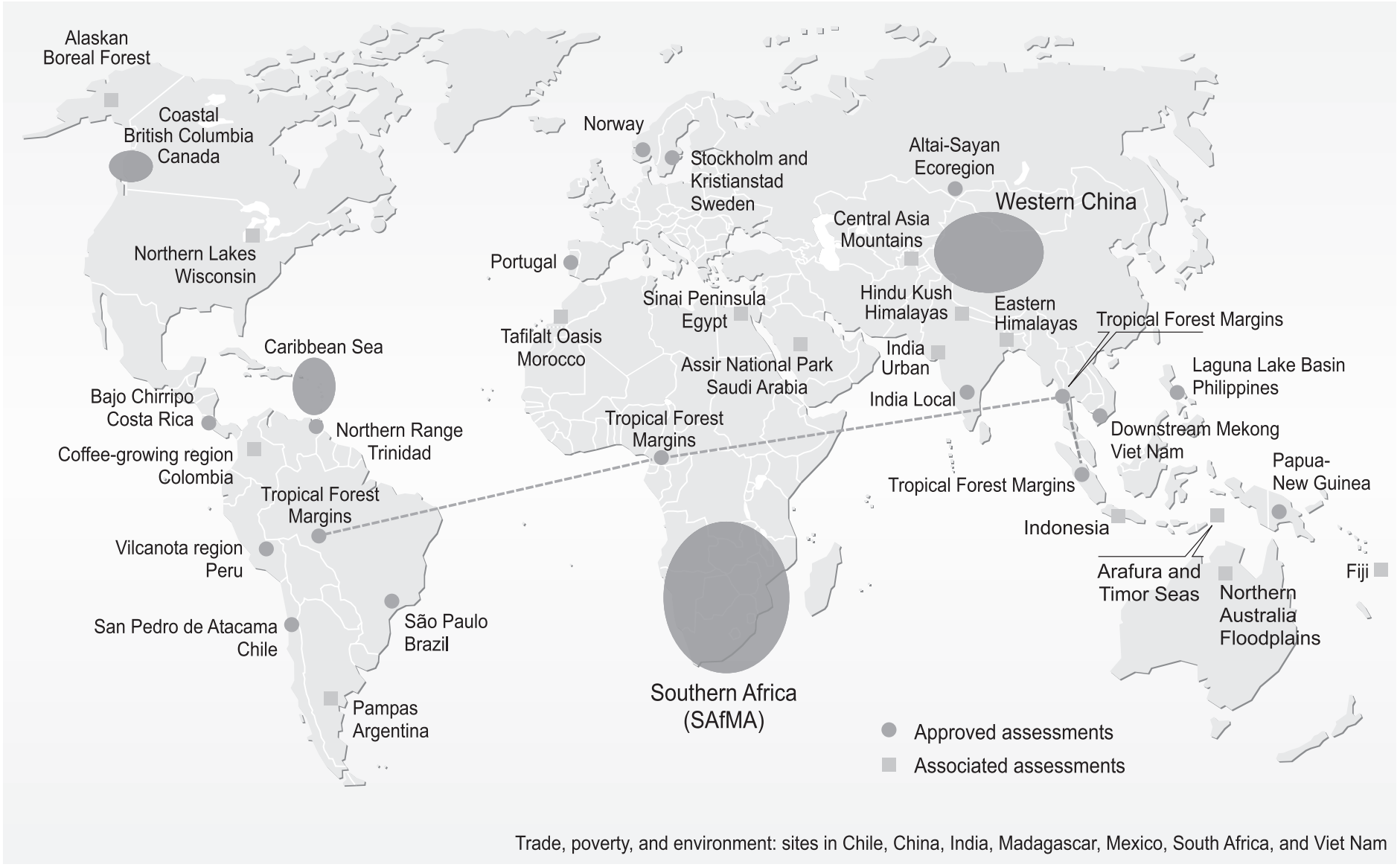
The conceptual framework for the MA posits that people are integral parts of ecosystems and that a dynamic interaction exists between them and other parts of ecosystems, with the changing human condition driving, both directly and indirectly, changes in ecosystems and thereby causing changes in human well-being. At the same time, social, economic, and cultural factors unrelated to ecosystems alter the human condition, and many natural forces influence ecosystems. Although the MA emphasizes the linkages between ecosystems and human well-being, it recognizes that the actions people take that influence ecosystems result not just from concern about human well-being but also from considerations of the intrinsic value of species and ecosystems. Intrinsic value is the value of something in and for itself, irrespective of its utility for someone else.

The Millennium Ecosystem Assessment synthesizes information from the scientific literature and relevant peer-reviewed datasets and models. It incorporates knowledge held by the private sector, practitioners, local communities, and indigenous peoples. The MA did not aim to generate new primary knowledge but instead sought to add value to existing information by collating, evaluating, summarizing, interpreting, and communicating it in a useful form. Assessments like this one apply the judgment of experts to existing knowledge to provide scientifically credible answers to policy-relevant questions. The focus on policy-relevant questions and the explicit use of expert judgment distinguish this type of assessment from a scientific review.

Five overarching questions, along with more detailed lists of user needs developed through discussions with stakeholders or provided by governments through international conventions, guided the issues that were assessed:

- What are the current condition and trends of ecosystems, ecosystem services, and human well-being?
- What are plausible future changes in ecosystems and their ecosystem services and the consequent changes in human well-being?
- What can be done to enhance well-being and conserve ecosystems? What are the strengths and weaknesses of response options that can be considered to realize or avoid specific futures?
- What are the key uncertainties that hinder effective decision-making concerning ecosystems?
- What tools and methodologies developed and used in the MA can strengthen capacity to assess ecosystems, the services they provide, their impacts on human well-being, and the strengths and weaknesses of response options?

The MA was conducted as a multiscale assessment, with interlinked assessments undertaken at local, watershed, national, regional, and global scales. A global ecosystem assessment cannot easily meet all the needs of decision-makers at national and sub-national scales because the management of any



Eighteen assessments were approved as components of the MA. Any institution or country was able to undertake an assessment as part of the MA if it agreed to use the MA conceptual framework, to centrally involve the intended users as stakeholders and partners, and to meet a set of procedural requirements related to peer review, metadata, transparency, and intellectual property rights. The MA assessments were largely self-funded, although planning grants and some core grants were provided to support some assessments. The MA also drew on information from 16 other sub-global assessments affiliated with the MA that met a subset of these criteria or were at earlier stages in development.

SUB-GLOBAL ASSESSMENT	ECOSYSTEM TYPES										ECOSYSTEM SERVICES								
	COASTAL	CULTIVATED	DRYLAND	FOREST	INLAND WATER	ISLAND	MARINE	MOUNTAIN	POLAR	URBAN	FOOD	WATER	FUEL and ENERGY	BIODIVERSITY-RELATED	CARBON SEQUESTRATION	FIBER and TIMBER	RUNOFF REGULATION	CULTURAL, SPIRITUAL, AMENITY	OTHERS
Altai-Sayan Ecoregion			●	●	●			●			●		●	●		●		●	
San Pedro de Atacama, Chile			●		●						●	●		●			●	●	●
Caribbean Sea	●					●	●				●	●		●				●	
Coastal British Columbia, Canada	●			●	●			●			●			●		●	●	●	
Bajo Chirripo, Costa Rica		●		●	●						●	●		●		●		●	●
Tropical Forest Margins		●		●							●	●		●	●	●	●		●
India Local Villages		●		●	●						●	●	●	●		●	●	●	●
Glomma Basin, Norway		●		●	●			●			●		●			●		●	●
Papua New Guinea	●	●				●	●				●	●	●	●		●	●	●	●
Vilcanota, Peru		●	●					●			●	●		●			●	●	●
Laguna Lake Basin, Philippines		●		●	●						●	●		●	●			●	●
Portugal	●	●	●	●	●	●	●	●		●	●	●		●	●	●	●	●	●
São Paulo Green Belt, Brazil	●	●		●	●					●	●	●		●	●	●	●	●	●
Southern Africa	●	●	●	●	●					●	●	●	●	●		●		●	●
Stockholm and Kristianstad, Sweden		●			●					●	●	●		●	●	●	●	●	●
Northern Range, Trinidad	●			●	●			●			●	●		●		●	●	●	●
Downstream Mekong Wetlands, Viet Nam	●	●			●						●	●	●	●	●	●	●	●	●
Western China		●	●	●	●			●			●	●		●	●		●		●
Alaskan Boreal Forest				●	●						●					●		●	●
Arafura and Timor Seas	●					●	●				●			●	●				●
Argentine Pampas		●									●	●						●	●
Central Asia Mountains								●			●	●		●					●
Colombia coffee-growing regions		●						●			●	●		●				●	
Eastern Himalayas				●				●			●	●	●	●				●	
Sinai Peninsula, Egypt			●					●						●			●	●	●
Fiji	●					●					●	●	●						●
Hindu Kush-Himalayas					●			●				●		●			●	●	●
Indonesia	●					●	●				●			●					●
India Urban Resource										●	●	●	●	●	●			●	●
Tafilalt Oasis, Morocco		●	●								●	●						●	●
Northern Australia Floodplains					●						●	●		●			●	●	●
Assir National Park, Saudi Arabia		●		●				●			●						●	●	●
Northern Highlands Lake District, Wisconsin				●	●							●				●	●	●	●

particular ecosystem must be tailored to the particular characteristics of that ecosystem and to the demands placed on it. However, an assessment focused only on a particular ecosystem or particular nation is insufficient because some processes are global and because local goods, services, matter, and energy are often transferred across regions. Each of the component assessments was guided by the MA conceptual framework and benefited from the presence of assessments undertaken at larger and smaller scales. The sub-global assessments were not intended to serve as representative samples of all ecosystems; rather, they were to meet the needs of decision-makers at the scales at which they were undertaken. The sub-global assessments involved in the MA process are shown in the Figure and the ecosystems and ecosystem services examined in these assessments are shown in the Table.

The work of the MA was conducted through four working groups, each of which prepared a report of its findings. At the global scale, the Condition and Trends Working Group assessed the state of knowledge on ecosystems, drivers of ecosystem change, ecosystem services, and associated human well-being around the year 2000. The assessment aimed to be comprehensive with regard to ecosystem services, but its coverage is not exhaustive. The Scenarios Working Group considered the possible evolution of ecosystem services during the twenty-first century by developing four global scenarios exploring plausible future changes in drivers, ecosystems, ecosystem services, and human well-being. The Responses Working Group examined the strengths and weaknesses of various response options that have been used to manage ecosystem services and identified promising opportunities for improving human well-being while conserving ecosystems. The report of the Sub-global Assessments Working Group contains lessons learned from the MA sub-global assessments. The first product of the MA—*Ecosystems and Human Well-being: A Framework for Assessment,* published in 2003—outlined the focus, conceptual basis, and methods used in the MA. The executive summary of this publication appears as Chapter 1 of this volume.

Approximately 1,360 experts from 95 countries were involved as authors of the assessment reports, as participants in the sub-global assessments, or as members of the Board of Review Editors. The latter group, which involved 80 experts, oversaw the scientific review of the MA reports by governments and experts and ensured that all review comments were appropriately addressed by the authors. All MA findings underwent two rounds of expert and governmental review. Review comments were received from approximately 850 individuals (of which roughly 250 were submitted by authors of other chapters in the MA), although in a number of cases (particularly in the case of governments and MA-affiliated scientific organizations), people submitted collated comments that had been prepared by a number of reviewers in their governments or institutions.

The MA was guided by a Board that included representatives of five international conventions, five U.N. agencies, international scientific organizations, governments, and leaders from the private sector, nongovernmental organizations, and indigenous groups. A 15-member Assessment Panel of leading social and natural scientists oversaw the technical work of the assessment, supported by a secretariat with offices in Europe, North America, South America, Asia, and Africa and coordinated by the United Nations Environment Programme.

The MA is intended to be used:

- to identify priorities for action;
- as a benchmark for future assessments;
- as a framework and source of tools for assessment, planning, and management;
- to gain foresight concerning the consequences of decisions affecting ecosystems;
- to identify response options to achieve human development and sustainability goals;
- to help build individual and institutional capacity to undertake integrated ecosystem assessments and act on the findings; and
- to guide future research.

Because of the broad scope of the MA and the complexity of the interactions between social and natural systems, it proved to be difficult to provide definitive information for some of the issues addressed in the MA. Relatively few ecosystem services have been the focus of research and monitoring and, as a consequence, research findings and data are often inadequate for a detailed global assessment. Moreover, the data and information that are available are generally related to either the characteristics of the ecological system or the characteristics of the social system, not to the all-important interactions between these systems. Finally, the scientific and assessment tools and models available to undertake a cross-scale integrated assessment and to project future changes in ecosystem services are only now being developed. Despite these challenges, the MA was able to provide considerable information relevant to most of the focal questions. And by identifying gaps in data and information that prevent policy-relevant questions from being answered, the assessment can help to guide research and monitoring that may allow those questions to be answered in future assessments.

Contents

Foreword xiii

Preface xv

Acknowledgments xvii

Reader's Guide xix

Summary: Integrated Assessments at Multiple Scales 1

Chapter 1. MA Conceptual Framework 15
Chapter 2. Overview of the MA Sub-global Assessments 29
Chapter 3. Linking Ecosystem Services and Human Well-being in the Sub-global Assessments 43
Chapter 4. The Multiscale Approach 61
Chapter 5. Using Multiple Knowledge Systems in Sub-global Assessments: Benefits and Challenges 85
Chapter 6. Assessment Process 119
Chapter 7. Drivers of Ecosystem Change 141
Chapter 8. Condition and Trends of Ecosystem Services and Biodiversity 171
Chapter 9. Responses to Ecosystem Changes and their Impacts on Human Well-being: Lessons from Sub-global Assessments 205
Chapter 10. Sub-global Scenarios 229
Chapter 11. Communities, Ecosystems, and Livelihoods 261
Chapter 12. Reflections and Lessons Learned 279

Appendix A: Color Maps and Figures 291
Appendix B: Brief Summaries of the Sub-global Assessments 311
Appendix C: Authors 367
Appendix D: Abbreviations and Acronyms 369
Appendix E: Glossary 373

Index 381

The Sub-global Working Group dedicates this volume to the memory of our friend and colleague, Dr. Gerhard Petschel-Held, who was an outstanding scientist and an exceptional human being. We are grateful for his friendship and contributions to the Millennium Ecosystem Assessment.

Foreword

The Millennium Ecosystem Assessment was called for by United Nations Secretary-General Kofi Annan in 2000 in his report to the UN General Assembly, *We the Peoples: The Role of the United Nations in the 21st Century.* Governments subsequently supported the establishment of the assessment through decisions taken by three international conventions, and the MA was initiated in 2001. The MA was conducted under the auspices of the United Nations, with the secretariat coordinated by the United Nations Environment Programme, and it was governed by a multistakeholder board that included representatives of international institutions, governments, business, NGOs, and indigenous peoples. The objective of the MA was to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being.

This volume has been produced by the MA Sub-global Assessment Working Group and summarizes lessons learned from the local, watershed, national, and regional assessments that were undertaken as part of the MA process. The material in this report has undergone two extensive rounds of peer review by experts and governments, overseen by an independent Board of Review Editors.

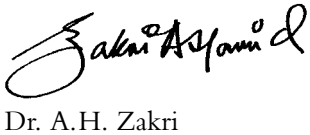
This is one of four volumes (*Current State and Trends, Scenarios, Policy Responses,* and *Multiscale Assessments*) that present the technical findings of the Assessment. Six synthesis reports have also been published: one for a general audience and others focused on issues of biodiversity, wetlands and water, desertification, health, and business and ecosystems. These synthesis reports were prepared for decision-makers in these different sectors, and they synthesize and integrate findings from across all of the working groups for ease of use by those audiences.

This report and the other three technical volumes provide a unique foundation of knowledge concerning human dependence on ecosystems as we enter the twenty-first century. Never before has such a holistic assessment been conducted that addresses multiple environmental changes, multiple drivers, and multiple linkages to human well-being. Collectively, these reports reveal both the extraordinary success that humanity has achieved in shaping ecosystems to meet the need of growing populations and economies and the growing costs associated with many of these changes. They show us that these costs could grow substantially in the future, but also that there are actions within reach that could dramatically enhance both human well-being and the conservation of ecosystems.

A more exhaustive set of acknowledgements appears later in this volume but we want to express our gratitude to the members of the MA Board, Board Alternates, Exploratory Steering Committee, Assessment Panel, Coordinating Lead Authors, Lead Authors, Contributing Authors, Board of Review Editors, and Expert Reviewers for their extraordinary contributions to this process. (The list of reviewers is available at www.MAweb.org.) We also would like to thank the MA Secretariat and in particular the staff of the Sub-global Assessment Working Group Technical Support Unit for their dedication in coordinating the production of this volume, as well as the WorldFish Center, which housed this TSU.

We would particularly like to thank the Co-chairs of the Sub-global Assessment Working Group, Dr. Doris Capistrano and Dr. Cristián Samper, and the TSU Coordinators, Marcus Lee and Ciara Raudsepp-Hearne, for their skillful leadership of this working group and their contributions to the overall assessment.

Dr. Robert T. Watson
MA Board Co-chair
Chief Scientist, The World Bank



Dr. A.H. Zakri
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Preface

This report presents an overview, synthesis, and analysis of the sub-global assessments that are part of the MA, and is based on information and results obtained through December 2004. It is important to note that a number of these assessments are still at the early stages, and a full set of results will not be available for another year or two. That said, a few assessments have now been completed and many interesting results are emerging from both these and on-going assessments. Recognizing the limitations of the challenging process that the MA Sub-global Working Group has undergone, this volume presents results from that process as a contribution to the set of core MA technical assessment reports. The sources of information that have been drawn on by the authors of this report are accordingly varied, reflecting the diverse nature and processes of the sub-global assessments (see Chapter 2, Box 2.1). To a limited extent, reference has also been made to relevant assessments at sub-global scales that were not directly involved in the MA process.

The MA sub-global assessments offer valuable insights and lessons on multidisciplinary, integrated, multiscale assessments attempting to respond to diverse needs of multiple stakeholders. This report was thus produced by the MA Sub-global Working Group not only to present a preliminary analysis of findings, but also to share lessons learned on the assessment process. This report serves to assist those sub-global assessments that are at the early stages of development, as well as other interested parties intending to undertake similar assessments of their own, to overcome some of the challenges they may encounter in designing and implementing their assessments.

The first chapters in this volume present the basic concepts on which the entire MA exercise was built, with particular reference to the design of the sub-global assessments. **Chapter 1** summarizes the MA Conceptual Framework, published in 2003. **Chapter 2** supplies the background information on the start-up and execution of the sub-global assessments, as well as on the Sub-global Working Group as a whole. **Chapter 3** presents an overview of the links between ecosystem services and human well-being found in the MA sub-global assessments. **Chapter 4** presents some of the basic concepts for conducting multiscale assessments and analyzes the choice of spatial and temporal scales in the different studies, along with the effects this had on the assessment process. **Chapter 5** offers a discussion on bridging different systems of knowledge and explores how the MA has encouraged the incorporation of multiple worldviews into the assessments and what the actual experience of various sub-global assessments with this has been. This is followed by an analysis of the assessment process in **Chapter 6,** which compares the different methods used for user engagement, governance, capacity-building, and communication with the users about both the process and assessment results.

The volume then turns to an analysis of key findings of, and patterns observed in, the sub-global assessments, based on the MA conceptual framework components assessed at the sub-global level. These include analysis of direct and indirect drivers of change (**Chapter 7**), conditions and trends (**Chapter 8**), response options (**Chapter 9**), and scenarios (**Chapter 10**). These are followed by a chapter on community assessments (**Chapter 11**), which reviews the MA sub-global findings from the perspective of community assessments and offers additional insights garnered from work at that level. The volume concludes by reflecting on the MA sub-global process and offers some important lessons and recommendations for future assessment work (**Chapter 12**).

The multiscale approach is one of the most innovative aspects of the MA, and this volume presents a synthesis of perspectives from multiple scales on ecosystems, the services they provide, and the consequences of change in service provision for human well-being. The sub-global assessment process includes a wide range of case studies from across the globe, from small tourism-reliant islands in the Caribbean to traditional mountain communities in the Andes, from small villages in India to large cities in Europe. Each of these studies was led by a local or national institution interested in using and adapting the MA framework, and we recognize that there are important ecosystems, services, and regions of the world that are not adequately represented.

We believe the strength of this process lies in the diversity of ecosystems and approaches presented in this volume. We have made an effort to combine conceptual analysis of the findings and process of the sub-global assessments with illustrative examples from the sub-global assessments throughout the various chapters. We believe that there is much to be gained from the insights and lessons drawn from emerging patterns and conclusions that are common, or indeed divergent, across the sub-global assessments analyzed.

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Reader's Guide

The four technical reports present the findings of each of the MA Working Groups: Condition and Trends, Scenarios, Responses, and Sub-global Assessments. A separate volume, *Our Human Planet*, presents the summaries of all four reports in order to offer a concise account of the technical reports for decision-makers. In addition, six synthesis reports were prepared for ease of use by specific audiences: Synthesis (general audience), CBD (biodiversity), UNCCD (desertification), Ramsar Convention (wetlands), business and industry, and the health sector. Each MA sub-global assessment will also produce additional reports to meet the needs of its own audiences.

All printed materials of the assessment, along with core data and a list of reviewers, are available at www.MAweb.org. In this volume, Appendix A contains color maps and figures. Appendix B provides brief summaries of the sub-global assessments. Appendix C lists all the authors who contributed to this volume. Appendix D lists the acronyms and abbreviations used in this report and Appendix E is a glossary of terminology used in the technical reports. Throughout this report, dollar signs indicate U.S. dollars and ton means tonne (metric ton). Bracketed references within the Summary are to chapters within this volume.

In this report, the following words have been used where appropriate to indicate judgmental estimates of certainty, based on the collective judgment of the authors, using the observational evidence, modeling results, and theory that they have examined: very certain (98% or greater probability), high certainty (85–98% probability), medium certainty (65%–58% probability), low certainty (52–65% probability), and very uncertain (50–52% probability). In other instances, a qualitative scale to gauge the level of scientific understanding is used: well established, established but incomplete, competing explanations, and speculative. Each time these terms are used they appear in italics.

Ecosystems and Human Well-being: Multiscale Assessments, Volume 4

Summary: Integrated Assessments at Multiple Scales

CONTENTS

1. **What Are the MA Sub-global Assessments?** 2

2. **What Did We Learn?** 2
   - *Ecosystem services are important for many dimensions of human well-being, some of which are best observed at sub-global scales.*
   - *The condition and trends of many ecosystem services, observed at multiple scales, are declining in many locations worldwide.*
   - *Identifying effective response options that enhance human well-being and conserve ecosystem services requires consideration of drivers at different scales and involvement of actors at the appropriate scales.*
   - *Local communities are not mere spectators, but active managers of the capacity of ecosystems to deliver services.*

3. **Why Conduct an Integrated Assessment at Multiple Scales?** 9
   - *The scale at which an assessment is undertaken significantly influences the problem definition and assessment results, as well as the solutions and responses selected.*
   - *Using different knowledge systems provides insights that might otherwise be missed.*

4. **What Are the Important Lessons for Future Sub-global Assessments?** . . 11
   - *The MA conceptual framework served as a valuable tool and initial point of reference, but had to be adapted by some sub-global assessments.*
   - *Multiscale assessments provide significant benefits, but they pose process and analytical challenges, are resource- and time-intensive, and, depending on assessment goals, may not always be necessary.*
   - *For success, a sub-global assessment requires understanding of the context, adequate resources, champions and actively engaged users, and a governance structure able to manage competing needs.*
   - *The sub-global assessment process has generated new tools and methodologies and baseline information that have helped to empower stakeholders; more products and outcomes will come to fruition in the future.*

1. What Are the MA Sub-global Assessments?

The MA, which focused on ecosystem change and the impacts of such change on human well-being, included a set of sub-global assessments at multiple spatial scales, in addition to the global assessment. This was one of the innovations of the MA compared to other international assessments, which usually focus on global or regional scales alone. The global and sub-global assessments analyzed ecosystem services and human well-being from different perspectives and with different stakeholders involved. The MA sub-global assessments were led by institutions and individuals in those countries where the sub-global assessments were carried out.

The MA sub-global assessments were conceived as integrated assessments to analyze the relationship between direct and indirect drivers of ecosystem change, their impact on ecosystem services, and the consequences for human well-being. They were also designed to compare different spatial scales, involve a diverse set of stakeholders, and use different knowledge systems as part of the assessment process. This volume presents an overview of the main outcomes and conclusions from this process, with reflections on the lessons learned.

The MA design for sub-global assessments was intended to develop and test methodologies for multiscale assessments, meet the information needs of decision-makers at every scale, and build capacity to undertake such assessments. The initial approach taken was to develop sets of nested, multiscale assessments in selected regions of the world, complemented by a ''cross-cutting'' assessment of similar ecosystems in different locations and an ''outlier'' assessment in an ecosystem or region not otherwise represented. As the process developed, however, a bottom-up approach was adopted, backed by an open call for proposals and a set of selection criteria related to assessment design and stakeholder engagement. Many sub-global assessments were established where demand and interest in such assessments arose. This resulted in a globally diverse set of assessments that were driven by user demand but did not represent a comprehensive selection or uniform sampling of ecosystems and locations around the world. [2]

The MA process included a total of 34 sub-global assessments from around the world. These assessments analyzed the importance of ecosystem services for human well-being at local, national, and regional scales. The areas covered in these assessments ranged from small villages in India, to cities like Kristianstad (Sweden) and São Paulo (Brazil), to whole countries like Portugal, and large regions like southern Africa. (See Figure SG1.) A short overview of each of the assessments involved is presented in Appendix B of this volume, and additional information is available on the MA website.

The MA design called for sub-global assessments covering multiple nested scales. For example, the Southern Africa sub-global assessment (SAfMA) included assessments of the entire region of Africa south of the equator, of the Gariep and Zambezi river basins in that region, and of local communities within those basins. (See Figure SG2.) This nested design was part of the overall design of the MA to analyze the importance of scale on ecosystem services and human well-being and to study cross-scale interactions. However, most sub-global assessments were conducted at a single spatial scale, with some multiscale analysis. [2, 4]

The sub-global assessments included a diversity of ecosystems. Examples include drylands in Chile and western China; tropical rainforests in the Amazon, Central Africa, and Southeast Asia; coastal and marine ecosystems in the Caribbean Sea and Papua New Guinea, and urban ecosystems in Sweden and Brazil, among others. Many assessments analyzed several ecosystems within a single study area. The majority of assessments (26 out of 34) included forests, inland water, or cultivated systems, which were the systems most commonly assessed. Island, coastal, and marine systems were not as widely represented (11 out of 34 assessed at least one of those systems), nor were urban systems (5 out of 34). Polar systems were not covered. [2]

The sub-global assessments involved a diversity of stakeholders in their processes, including local, regional and national governments, nongovernmental organizations, local communities, research and academic institutions, and, to a lesser extent, the private sector and international organizations. The institutions leading the assessments were different across assessments, but they were often academic or research institutions. Including a diversity of stakeholders is considered essential for effective assessments, as it enhances stakeholder ownership of the outcomes. [6]

2. What Did We Learn?

Ecosystem services are important for many dimensions of human well-being, some of which are best observed at sub-global scales.

People everywhere in the world rely on ecosystems for their well-being. The sub-global assessments provided many examples, at all scales, from local to global; in all parts of the world, from the least to the most developed; and for all peoples, from the poorest to the wealthiest, from the most rural to the most urban. Some ecosystems provide direct benefits for people: forest dwellers in Papua New Guinea harvest foods from the rainforest, fishermen in Trinidad harvest fish from the ocean, local populations in Viet Nam use plant species for medicinal purposes, and villagers in Zambia rely on wood for a variety of needs. (See Box SG1.) In other cases, the benefits from ecosystems come from regulating services essential to human well-being. Evidence suggests that the people of São Paulo, Brazil, benefit from the surrounding belt of forest that regulates both the temperature and the quality of the air in the city. The wetlands in Kristianstad, Sweden, have an important function in buffering the local population from annual flooding events. Ecosystems can also provide important cultural and spiritual services for local communities in both rural and urban settings. [3]

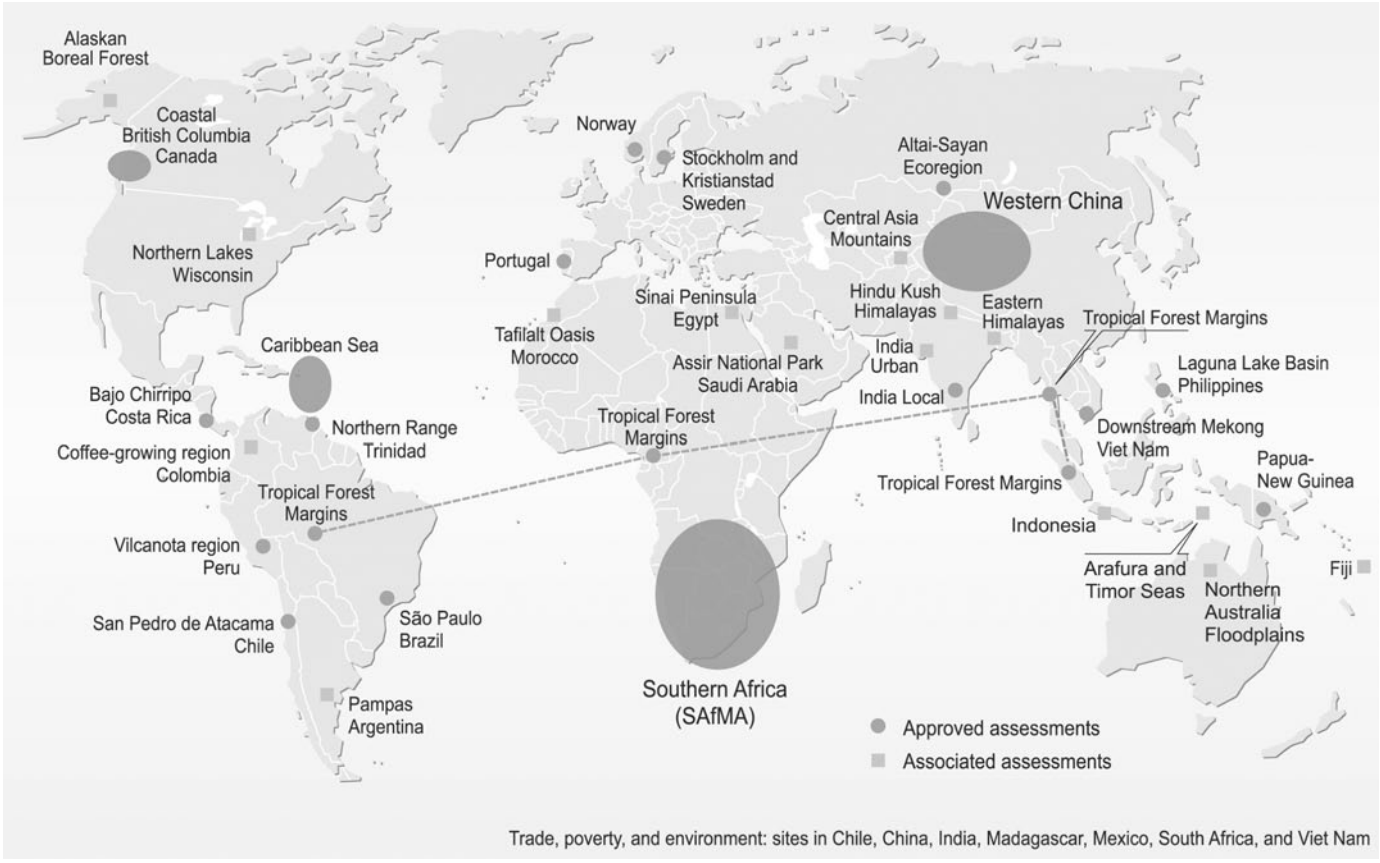


Figure SG1. Map Showing the Global Distribution of Sub-global Assessments that were Part of the Millennium Ecosystem Assessment (MA). The approved assessments were formally approved by the MA Board and followed all the guidelines of the MA, including an analysis of all components of the conceptual framework. Associated assessments used the conceptual framework, but did not necessarily analyze all components.

Spiritual and cultural services are regarded as important ecosystem services at local scales, for wealthy as well as for poor communities and in both rural and urban settings. Several assessments conducted with and by local communities highlighted the importance of spiritual and cultural services. For example, local villages in India preserve selected sacred groves of forest for spiritual reasons. Urban parks provide important cultural and recreational services in cities around the world, such as in Stockholm, where the principal urban park receives some 15 million visits every year. (See Box SG2.) [3]

There are clear trade-offs among ecosystem services; the nature of these trade-offs are context-specific and differ across assessments. The analyses performed by the sub-global assessments, in agreement with the global results, generally show an increase in provisioning services over time, at the expense of regulating services, supporting services, and biodiversity. For example, deforestation caused by increased local demand for wood resulted in an increase in human disease in India (see Box SG3), and mining and tourism activities in San Pedro de Atacama in Chile have had an impact on the availability and access to water by local populations. [3]

The relationship between ecosystem services and human well-being can take on several different forms. The sub-global assessments found a wide range of relationships between ecosystem services and human well-being. Often, rising incomes are initially accompanied by declines in some ecosystem services. In the assessment of the downstream Mekong wetlands in Viet Nam, for example, economic growth from agricultural expansion has improved human well-being, but at the expense of soil quality. Once a sufficient level of wealth is achieved, societal priorities may emphasize the quality of the environment and the services it delivers. This was most obvious in the assessment of the Stockholm Urban Park, Sweden, where stakeholders are minimizing the impacts of urban sprawl. In some cases, there is no evidence for such a turnaround, and some services may decline continuously with increasing wealth. For instance, water as a provisioning service continues to be degraded in the wealthy, urban area of Gauteng in South Africa. In yet other cases, a particular service may possibly improve continuously in tandem with increasing wealth, which would be the case in Viet Nam if increasing agricultural production were managed sustainably. The sub-global assessments did not equate human well-being with wealth, but wealth was an important and frequently measured component of well-being. [3]

In places where there are no social safety nets, diminished human well-being tends to increase im-

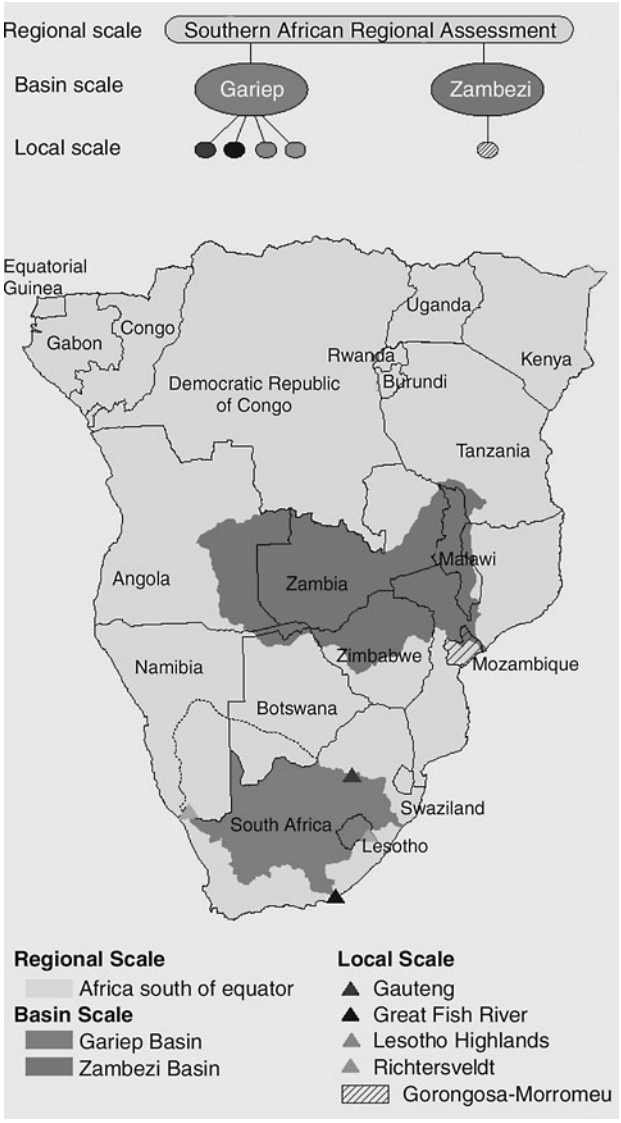


Figure SG2. The Multiscale Assessment in Southern Africa and its Nested Design. The assessment consisted of a regional component which included all countries in Africa south of the equator, basin assessments of the Gariep and Zambezi rivers, and five local assessments within those basins.

BOX SG1

Fuelwood, Water, and Health in Zambia

In the Kafue basin of Zambia, wood constitutes 96% of household energy consumption. Shortage of wood fuel occurs in areas with high population density without access to alternative and affordable energy sources. In those provinces of Zambia where population densities exceed the national average of 13.7 persons per square kilometer, the demand for wood has already surpassed local supply. In such areas, people are vulnerable to illness and malnutrition because it is too expensive to heat homes, not possible to cook food, and consumption of unboiled water facilitates the spread of waterborne diseases such as cholera. Women and children in rural poor communities are the most affected by wood fuel scarcity. They must walk long distances searching for firewood, and therefore have less time for tending crops, cooking meals, or attending school.

BOX SG2

Recreation in Urban Parks in Sweden

The National Urban Park in Stockholm, Sweden, receives 15 million visitors per year, most of whom visit the park for recreational purposes. More than 90% of the urban population in Stockholm visits the city's green area at least once a year, and about half of those visit at least weekly. Recreation in this park system promotes physical exercise and mental well-being. The green area allows humans to come into contact with nature and provides a resource for natural science teaching.

BOX SG3

Deforestation and Human Disease in India

In Koyyur village, India, deforestation has resulted in increased human disease. Growing demand for wood and other forest products caused an increase in canopy gaps in the rainforest, which allowed more sunlight to reach the forest floor. The resulting increased growth of grasses and other fodder species attracted cattle from the villages. These cattle carry ticks that transmit a monkey fever (Kyasanur forest disease) that affects people, resulting in an increase in the disease in humans.

mediate dependence on ecosystem services. The resultant additional pressure can damage the capacity of those local ecosystems to deliver services, and this capacity can decline to such a degree that the probability of disaster or conflict increases. For example, rural communities in the former tribal ''homelands'' in South Africa had no rights of permanent residence outside those areas, and they had few economic opportunities within them. As a result, they depended on the ecosystem resources that the areas offered, and in many cases overexploited them. In this type of relationship between poverty and the environment, particularly when property rights are not clearly defined and resource management institutions are weak, poor people can sink further into poverty as they are driven to participate in unsustainable resource use regimes. [11]

Inequities in the distribution of the costs and benefits of ecosystem change are often displaced to other places, groups, or future generations. For example, the economic clout of cities enables many urban populations to draw on resources from distant ecosystems, and this trend is expected to continue with increasing urbanization; the Gariep basin assessment, for example, showed that the population of the urban area of Gauteng province in South Africa consumes nearly 30 times more wheat than is produced in the province itself. The increase in international trade is also generating additional pressures on ecosystem services around the world, illustrated in the cases of the mining industries in Chile (see Box SG4) and Papua New Guinea. In some cases, the costs of transforming ecosystems are simply deferred to future generations. An example reported widely across sub-global assessments in different parts of the world

BOX SG4

Mining, Water, and Human Well-being in Chile

San Pedro de Atacama, Chile, is located within the driest desert in the world. Surface water is limited. The present major concern is over groundwater usage and the extent to which its exploitation is sustainable. The economic activities in this area include mining, agriculture, and tourism, all of which depend on the quantity and quality of available water. The Salar de Atacama (a salty wetland) holds over 40% of world lithium reserves; mining provides 12% of employment in the municipality; and two-thirds of the regional GDP. Mining is the most important user of groundwater (almost 100% of groundwater rights). Tourism is the second largest source of employment and income, and needs fresh water for its facilities (potable water amounts to 16% of surface water rights). Local communities rely on water for subsistence agriculture and livestock raising (accounting for 83% of surface water rights). Most subsistence farmers do not have enough resources to buy water rights, when bidding against other users. Hence the shortage of water generates major conflicts over access and ownership rights among the competing users.

was tropical deforestation, which caters to current needs but leads to a reduced capacity to supply services in the future.

The condition and trends of many ecosystem services, observed at multiple scales, are declining in many locations worldwide.

The sub-global assessments showed that ecosystem services are declining in many regions around the world. Despite some gains in the provisioning of food, water, and wood, the ecological capacity of the systems to continue to provide services is at risk in several locations. Problems with provisioning services include deterioration of water quality, deterioration of agricultural soils, and insufficient supply to meet demand. Some of the threats affecting regulating services are loss of forest cover, rangeland degradation by overgrazing (particularly in drylands), loss of wetlands to urban development and agriculture, and change in fire frequency. Problems with cultural services include loss of cultural identity and negative impacts from tourism. Biodiversity is decreasing due to the loss and fragmentation of natural habitats and the reduction of species population sizes, particularly of large bodied species, species occupying high trophic levels, and species that are harvested by humans. [8]

Conclusions on conditions and trends may differ between global and sub-global analyses. Although there was overall congruence in the results from global and sub-global assessments for services like water and biodiversity, there were instances where local assessments showed the condition as either better or worse than expected from the global assessment. For example, the condition of water resources, as assessed in the sub-global assessments, was significantly worse than might have been expected from the global assessment in places like São Paulo (Brazil) and the Laguna Lake Basin (Philippines). (See Figure SG3.) On the other hand, biodiversity condition in the Gorongosa-Marromeu component of the southern Africa assessment (SAfMA) was assessed to be better than the global assessment suggested. There were more instances of results differing between the global and sub-global analyses for biodiversity than for water provisioning, because the concepts and measures of biodiversity were more diverse in the sub-global assessments. [8]

The biophysical drivers of change mentioned most often across the sub-global assessments were land use change, climate change and variability, pollution, and invasive species. These drivers were seen, at best, as only partially under the control of the decision-maker at the particular scale of analysis. Land use change comprises a whole range of processes, including urbanization and urban growth (for example, São Paolo or Portugal), encroachment on natural ecosystems by agriculture (for example, Eastern Himalayas or Coastal British Columbia), and infrastructure development (for example, Tropical Forest Margins or the Caribbean Sea). A striking example of invasive species is in the Caribbean Sea, where dust blown from the Sahara across the Atlantic introduced new pathogenic bacteria that were at least partially responsible for coral reef diseases in the last two decades. [7]

Economic growth, structural change, and globalization were the most commonly identified indirect drivers. Their impacts on ecosystems are mediated by institutional and sociopolitical factors. Evidence from the sub-global assessments suggests that the impact of these indirect drivers depends on a range of institutional settings and on the structure of growth itself. The economic changes of the 1990s introduced a market system in the Altai-Sayan ecoregion in Russia and Mongolia. This resulted in higher cashmere producer prices, which in turn encouraged intensification of herding and the movement of herd locations closer to marketplaces, thus inducing overstocking in surrounding areas. On the other hand, in Trinidad, the liberalization of trade and the resulting competition forced down local prices of produce, which made local production of market crops uneconomical. The increase in transport triggered by global trade is seen as a major indirect driver for increases in species invasions. For example, the release of ballast water by ships coming from the Indo-Pacific region resulted in the introduction of the green mussel *Perna veridis* to Trinidad in the early 1990s. The mussel clogs up the intake pipes of industrial facilities in Trinidad, costing millions of dollars annually to remove. In a period of ten years, the mussel spread across the Caribbean all the way to Tampa Bay, Florida. However the mussel is also being harvested as a source of food in some parts of the Caribbean. [7]

Interactions among the drivers of ecosystem change in the sub-global assessments were seen to be of three major types: processes that trigger, reinforce, or constrain one another. The introduction of EU policies in Portugal *triggered* a high degree of dependency on decisions made at the European level, which in some cases may not be appropriate for local decision-making on ecosystems and their services. The Tropical Forest Margins assessment revealed that the resettlement projects designed to relieve pressures on the natural and social environment in the densely populated regions of coastal Southeast Asia have

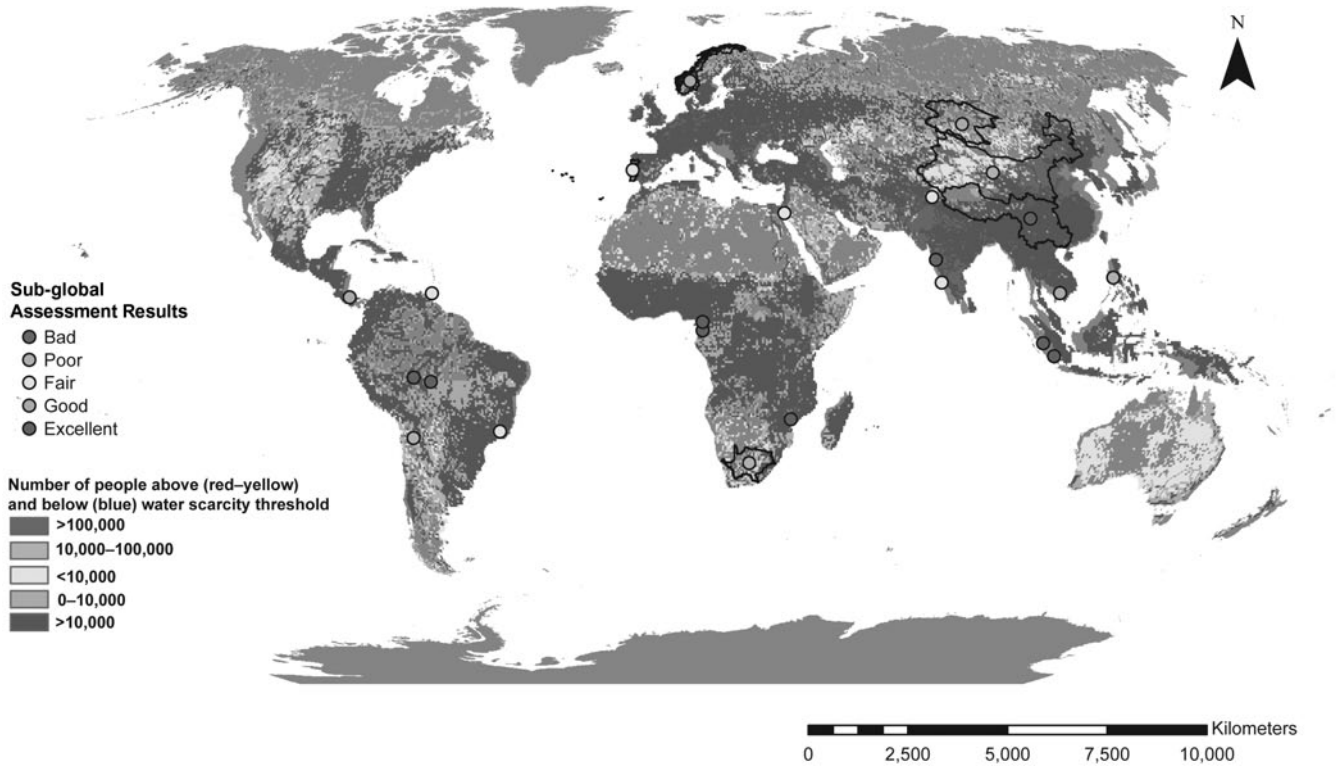


Figure SG3. Comparison between Freshwater Condition in the Sub-global Assessments and the Global Distribution of Human Population in 1995 Relative to a Threshold of Severe Water Scarcity. This map shows the distribution of the human population which faces severe water limitations (i.e., which is above the water scarcity threshold). The threshold corresponds to a ratio of 40% of water use or withdrawal to discharge (Vörösmarty et al. 2000). Boundaries of sub-global assessments that assess large areas are plotted in black.

reinforced processes of land use change, with swidden agriculture being the main driver in the processes of deforestation in the tropical forest margins. Cases where one driver is *constrained* by the action of another serve as a starting point for appropriate interventions. In the Stockholm Urban assessment in Sweden, for example, institutional change is a potentially effective intervention because it can constrain urban sprawl, a major driver of loss of green areas. [7]

Drivers of change act in very distinct ways in different regions. Though similar drivers were present in different assessments, their interactions, and thus the processes leading to ecosystem change, differed significantly from assessment to assessment. Though the three regions of the Amazon, Central Africa, and Southeast Asia in the Tropical Forest Margins assessment have the same set of individual drivers of deforestation, the processes of change in each region are distinct. Deforestation driven by swidden agriculture is more widespread in upland and foothill zones of Southeast Asia than in other regions. Road construction by the state followed by colonizing migrant settlers, who in turn practice slash-and-burn agriculture, is most frequent in lowland areas of Latin America, especially in the Amazon Basin. Pasture creation for cattle ranching is causing deforestation almost exclusively in the humid lowland regions of mainland South America. The spontaneous expansion of smallholder agriculture and fuelwood extraction for domestic uses are important causes of deforestation in Africa. While human-controlled drivers play a major role in determining the condition of ecosystem services, local biophysical constraints such as climate and soils also limit the production of ecosystem services. [7]

Drivers operate over different spatial and temporal scales, and the spatial and temporal scales of any given driver may be related in different ways. For a large number of drivers identified in the different sub-global assessments, drivers operating over large spatial areas tended to be associated with slower processes of change, while ''small'' processes tended to take place relatively rapidly. However, a significant number of exceptions to this pattern were observed. For example, the São Paulo assessment mentioned governance and legislation as a local, but slow driver. The same held for soil degradation as a biophysical driver in Viet Nam. On the other hand, in San Pedro de Atacama, Chile, the rapid change of technology in the mining sector taking place globally appeared as an important driver. This characteristic of technology—that is, fast change at the global, or at least national, scale—also held for the Argentine Pampas. [7]

Identifying effective response options that enhance human well-being and conserve ecosystem services requires consideration of drivers at different scales and involvement of actors at the appropriate scales.

Understanding drivers, their interactions, and the consequences for ecosystem services and human

well-being is crucial to the design of effective responses. Although many responses target specific problems with ecosystem services, the nature of ecosystems means that such responses can have unintended consequences for multiple interacting drivers. Individual drivers may be difficult to influence without affecting others, and therefore response options targeted at interactions among drivers are often a more effective way to achieve a desired outcome, and may enable a more integrated and holistic approach to ecosystem service management. The adaptive co-management approach adopted by the Kristianstad Wetlands assessment in Sweden is an example; adaptive co-management systems are flexible, community-based systems of resource management tailored to specific places and situations, supported by, and working with, various organizations at different levels. Similarly, the river rehabilitation councils in the Laguna Lake Basin of the Philippines addressed a number of social and ecological drivers and engaged various stakeholders at different scales, resulting in several effective responses. [7, 9]

Scenario-building is an important method for involving stakeholders in policy formulation and for encouraging citizens to adopt their own policies aimed at environmental protection. The relevance, significance, and influence of the scenarios that are constructed will ultimately depend on who is involved in their development. Decision-makers may have difficulty introducing new policies designed to alter behaviors without the support of the general population. Participants in scenario-building can provide essential input on the relevance of storylines being developed and on the nature of uncertainties that are important at sub-global scales. [10]

Sub-global assessments used scenarios for multiple purposes, which often extended beyond the rationale for global scenarios. Besides being used by all of the sub-global assessments as a tool for decision-makers to plan for the future (as in the global scenarios), most sub-global assessments, such as SAfMA and the Northern Highlands Lake District of Wisconsin, also used scenarios as a means of communicating possible future changes and major uncertainties to stakeholders. In the San Pedro de Atacama, Chile, and the Bajo Chirripó, Costa Rica, assessments, for example, scenarios also proved to be an important tool for acquiring data about stakeholder preferences, perceptions, and values. In a few cases, including the Wisconsin, Caribbean Sea, and SAfMA assessments, scenarios had a role in defining the boundaries within which discussions about management and policy options relevant to ecosystem services and human well-being could be held. All of these examples also illustrate the use of participatory scenario development approaches in the sub-global assessments. [10]

Scenarios in the sub-global assessments differed markedly from the scenarios developed at the global level, although all were based on the same conceptual framework. The most significant differences were in terms of key uncertainties (which were much more context-specific at the local level), stakeholders involved, and the scales of analysis. Almost all sub-global scenarios identified institutional arrangements/governance as the key uncertainty, even with widely varying ecological and socioeconomic circumstances across the sub-global assessments. Many sub-global assessments sought to quantify the scenario storylines, but time constraints and the lack of available models prevented many from doing so, with the exception of the Western China and SAfMA Regional assessments. (See Figure SG4.) Nonetheless, substantive links were maintained with the global scenarios in the SAfMA, Caribbean Sea, and Portugal assessments, for example, through the use of global models in the development of regional scenarios. [10]

The effectiveness of a response is related to the degree of coherence among different types of policies and the degree of collaboration among stakeholders. Horizontal (multisector) collaboration ensures that multiple objectives (ecological, social, cultural, economic) are addressed in an integrated fashion. Vertical (multilevel) collaboration facilitates the generation of resources and increases the likelihood that responses have a positive impact on direct and indirect drivers of ecosystem change. Since these drivers typically occur at a continuum of social and ecological scales, responses would need to involve decision-makers (and actors) at multiple organizational levels. For instance, local responses such as coping and adapting to environmental change by the Bedouins in Egypt and by local communities in southern Africa have been largely ineffective due to the lack of institutional and financial support at the national level. In contrast, local people in the Eastern Himalayas took the initiative to form eco-development committees, and this became an effective response thanks to facilitative support from legislators. Collaboration is not only a local phenomenon; it has been initiated by all categories of actors operating at all identified organizational levels. [9]

Collaboration among actors is often facilitated by ''bridging organizations.'' These provide arenas for multisector and/or multilevel collaboration for conceiving visions, trust-building, collaboration, learning, value formation, conflict resolution and other institutional innovations. Bridging organizations lower the transaction costs of collaboration and of crafting effective responses. They provide social incentives to identify possible win-win responses. The facilitation, leadership, and social incentives provided by bridging organizations or key persons in the community appear to be essential for capacity-building. For instance, in Kristianstad Wetlands, Sweden, a new organization called Ecomuseum has initiated a process based on collaboration, trust-building, and conflict resolution. Through voluntary participation within the existing legal framework, the ecosystem approach has been applied and an area with declining ecosystem services is now being transformed into a UNESCO Biosphere Reserve. In the Laguna Lake Basin of the Philippines, public agencies and nongovernmental organizations formed river rehabilitation councils that have been able to address social and ecological drivers in a collaborative and effective way. In San Pedro de Atacama, Chile, the assessment team provided the arena for collaborative learning, trust-building, visioning, and conflict resolution. These three examples illustrate the formation of bridging

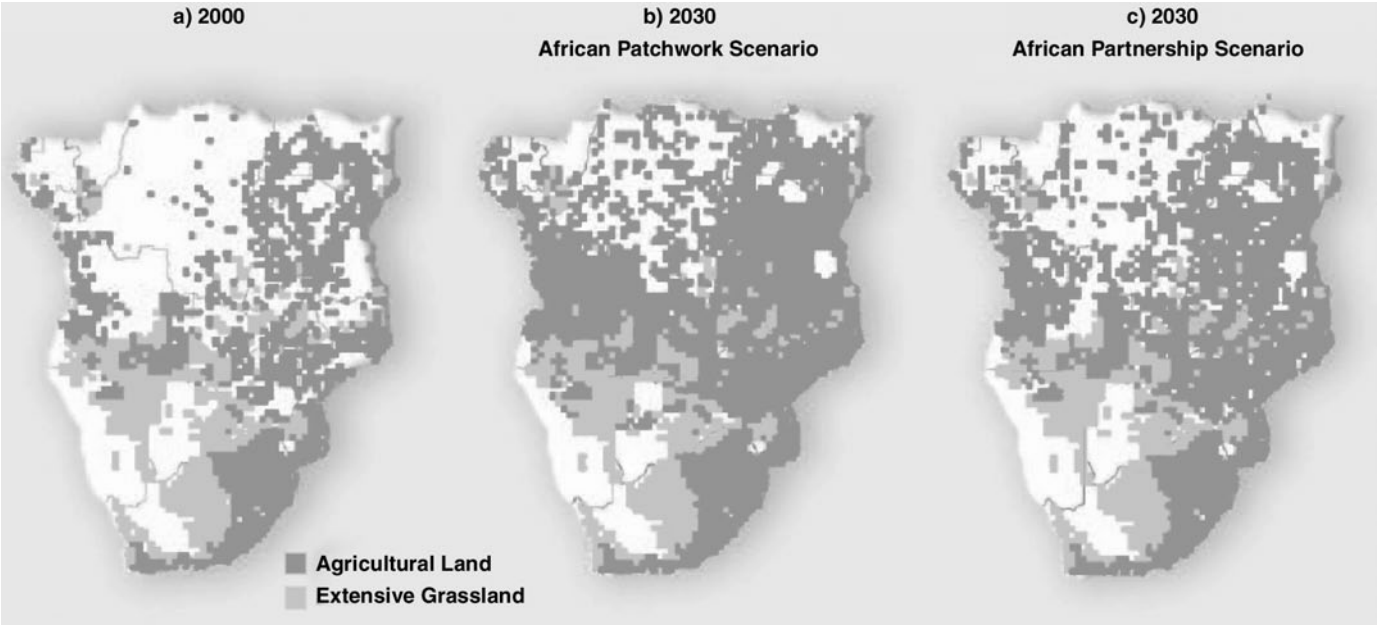


Figure SG4. Scenarios for Land Use Change in Southern Africa, 2000–2030. Under the Patchwork Scenario (low economic growth scenario), a greater area is converted to agriculture than under the Partnership Scenario (high economic growth). In both cases, the major changes occur north of the Zambezi river and are mainly due to increased livestock numbers rather than increased crop area. The model assumes that livestock are grazed extensively in the grassland areas and intensively on a portion of the area otherwise used for agriculture.

organizations that have resulted from bottom-up, top-down, and external initiatives, respectively. [9]

Declining ecosystem trends have been mitigated by innovative local responses. The "threats" observed at an aggregated, global level may be overestimated or underestimated from a sub-global perspective. Assessments at an aggregated level may fail to take into account the adaptive capacity of sub-global actors. Through collaboration in social networks, actors can develop new institutions and reorganize to mitigate declining conditions. On the other hand, in crafting their responses, sub-global actors tend to neglect drivers that are beyond their immediate influence. Hence, it is crucial for decision-makers to develop institutions at the global, regional, and national levels that strengthen the adaptive capacity of actors at the sub-national and local levels to develop context-specific responses that do address the full range of relevant drivers. The Biodiversity Management Committees in India are a good example of a national institution that enables local actors to respond to biodiversity loss. This means neither centralization nor decentralization but institutions at multiple levels that enhance the adaptive capacity and effectiveness of sub-national and local responses. [9]

When people with different interests, experiences, and knowledge cooperate, the potential diversity and effectiveness of response options is enhanced. Besides the democratic appeal of public participation, the knowledge base is broadened when local, traditional, and indigenous knowledge systems are acknowledged. By close monitoring of a diverse set of ecological variables, local stewards are often able to observe and understand early signals of ecosystem change, and distinguish this from natural variability. This is illustrated by Kristianstad Wetlands, Sweden, where local steward organizations observed declining bird populations and other signals that sparked the formation of a bridging organization. [9]

Local communities are not mere spectators, but active managers of the capacity of ecosystems to deliver services.

Ecosystems provide a sense of place and identity for local people, in addition to other ecosystem services. These intangible values, including aesthetic and recreational values, provide a rationale for management and precipitate management practices that enhance ecosystem resilience through caretaking and custodianship. In Vilcanota, Peru, spiritual values and belief systems, including the belief in Pacha Mama (Mother Earth) that encompasses the view that Earth is a living being, have allowed for the maintenance of a cultural identity among the Quechua peoples of the southern Peruvian Andes. In the Kristianstad Wetlands, Sweden, local farmers have once again begun to cultivate land previously abandoned, not primarily for economic gain, but more for the sense of place and identity that comes with the cultivation of this land. However, in many instances these values and belief systems have been eroded, leading to a shift in community-based management practices. For example, in San Pedro de Atacama, Chile, the erosion of the collective indigenous identity due to economic development has led to the sale of land to outsiders, and a consequent decline in agriculture and related traditional practices. [11]

Diversity in ecosystems and their services is important in reducing communities' vulnerability. Most

communities seek to maintain a diversity of livelihood options. This diversity buffers people against shocks and surprises such as climatic and economic fluctuations. In Papua New Guinea and India, for example, local farmers cultivate a wide variety of crops to avert the risk of crop failure. In Costa Rica, local communities create a mosaic landscape, consisting of sacred places, springs, agroecosystems, and high mountains. This results in a diversity of livelihood options at the local level. [11]

Local management systems are continuously evolving; some disappear while others are revived or newly invented. Many communities possess local, indigenous, or traditional knowledge about the interactions between humans and ecosystems. Local communities can affect ecosystem services and human well-being both positively and negatively. For example, in Xinjiang, western China, local people have elaborate traditional underground water harvesting structures (''karez'') that maintain both water quality and quantity. Traditional community institutions that regulate access to the karez water exist, but in some cases are being weakened. In the Eastern Himalayas, India, economic incentives for private forest owners have led in some instances to deforestation in native forests. Nevertheless, the recognition of the role of communities as stewards of ecosystem services, and their empowerment, is essential to strengthen local capacity to manage ecosystems sustainably for human well-being. [11]

Communities are affected by larger-scale processes, but their ability to cope with and shape change varies. Decisions taken at higher scales often do not take into account the realities of local communities, resulting in negative impacts at the local level. Communities that cope successfully with these external forces have learned to adapt or even take advantage of them by creating horizontal links with other groups, forming alliances with powerful actors at ''higher'' spatial scales, and linking with national or global processes such as policy forums, markets, and multinational agreements. The Vilcanota assessment in Peru is driven by the indigenous communities there to meet their own needs, and the link to the global MA process has provided benefits to both these communities and the wider MA process. When conditions become impossible to adapt to, for example due to inflexible national policies, people are forced to migrate or face a reduced quality of life. In Sistelo, Portugal, for example, a government afforestation program on common property land (*baldio*) diminished the locally available livelihood and coping strategies by reducing land available for pastoralism, thereby accelerating the process of rural-urban migration. [11]

3. Why Conduct an Integrated Assessment at Multiple Scales?

The scale at which an assessment is undertaken significantly influences the problem definition and assessment results, as well as the solutions and responses selected.

A *comprehensive* multiscale assessment incorporates at least two nested-levels of complete, interacting assessments, each with a distinct user group, problem definition, and expert group. While the overall MA process was a multiscale assessment as defined here, the sub-global assessments ranged from comprehensive multiscale assessments to single scale assessments with explicit multi-scale linkages or considerations. Only two sub-global assessments were conducted as *comprehensive* multiscale assessments with separate assessments at different scales (Southern Africa and Portugal). Other assessments, such as the Argentine Pampas, Coastal British Columbia, Colombia, and Western China, included significant *multiscale analyses* (for example, detailed case studies of particular sub-regions within the overall assessment) but were not *comprehensive* multiscale assessments since the case studies did not include their own user groups and problem definitions. All of the MA sub-global assessments examined processes that occur at multiple scales. [4]

The scale at which an assessment is undertaken significantly influences the problem definition and the assessment results. Findings of assessments conducted at different scales will differ due to differences in the questions posed and/or the information analyzed. Local communities are influenced by global, regional, and local factors. *Global* factors include commodity prices—for example, global trade asymmetries that influence local production patterns, as in Colombia (see Box SG5), Portugal, SAfMA Gariep, and Altai-Sayan—and global climate change. Examples of the latter include sea level rise (Papua New Guinea) and receding glaciers (Vilcanota, Peru, and Altai-Sayan). *Regional* factors include water supply regimes (for example, safe piped water in rural areas, as in SAfMA Gariep), regional climate (desertification as in Portugal), and geomorphological processes (soil erosion and degradation, as in Altai-Sayan and Trinidad). *Local* factors include market access (for example, distance to market, as in Papua New Guinea), disease prevalence (malaria, as in India Local and Papua New Guinea), or localized climate variability (patchy thunderstorms, as in SAfMA Gariep). Assessments conducted at different scales tend to focus on drivers and impacts most relevant at each scale, yielding different but

BOX SG5

Coffee and Forests in Colombia

The coffee-growing region of Colombia encompasses an area of more than 3.6 million hectares in the Andes, of which 870,000 hectares are currently devoted to coffee plantations. Coffee is grown in 605 municipalities in the country (56% of the national total), and involves 420,000 households and more than half a million agricultural productive units or farms. The old coffee plantations using varieties that were grown under shade trees were replaced with higher yield varieties that grow in open areas, leading to the loss of tree cover. The expansion of coffee production in other parts of the world (for example, Viet Nam) contributed to a reduction in international prices, resulting in a shift in agricultural production and changes in landscape use in the coffee-growing region of Colombia.

complementary findings. These provide some of the benefit of a multiscale assessment process, since each component assessment provides a different perspective on the issues addressed. [4]

A full multiscale assessment provides a powerful basis for evaluating the robustness and persistence of findings across scales. If an assessment of surface water availability finds that a specific region consistently experiences water scarcity across all the scales of analysis, the finding can be viewed with some degree of confidence. In contrast, if the same region is identified at one scale as water scarce, but is subsequently seen at another scale of analysis to exhibit varying degrees of scarcity and abundance, assessment teams are compelled to explore the possible reasons for such discrepancies. Inconsistency in findings across scales may stem from data or model inaccuracies or from local perceptions, needs, and/or requirements (for example, livelihood strategies at the local level that nullify broad-based patterns of access to subterranean water sources in areas that possess limited surface water). This full range of patterns emerged for different geographic areas in southern Africa analyzed by the regional, basin, and local scale assessments. [4]

Multiscale assessments offer insights and results that would otherwise be missed. The variability among sub-global assessments in problem definition, objectives, scale criteria, and systems of explanation increased at finer scales of assessment (for example, the visibility of social equity issues increased from coarser to finer scales of assessment). The role of biodiversity as a risk avoidance mechanism for local communities is frequently hidden until local assessments are conducted (examples include India Local; Sinai, Egypt; SAfMA Livelihoods). Processes of common concern emerging at all scales of assessment assumed different meanings and implications at different scales. For example, institutional responses at the global scale include formal global agreements and financial commitments, but at finer and finer sub-global scales, they increasingly involve relatively informal but effective efforts such as cooperative local resource management; examples include Caribbean Sea; India Local; Coastal British Columbia; Kristianstad Wetlands, Sweden. [4]

Using different knowledge systems provides insights that might otherwise be missed.

Local and traditional ecological knowledge added significant insight about locally important resources and management practices, revealing information and understanding that is not reflected in the global assessment. This included names and uses of locally important plant species and practices to protect them (examples include India Local and Sinai), local drivers of change, specialized soil and water conservation practices, and coping strategies to protect human well-being. Local resource users also contributed valuable long-term perspectives about their social-ecological systems (Bajo Chirripó, Costa Rica), as well as information on key ecosystem processes that are important, uncertain, and difficult to control (Wisconsin). [5]

Practitioner knowledge—the diverse knowledge of multiple stakeholders—contributed more in terms of clarifying information needs and expectations, and less in terms of ecosystem management knowledge. Few assessments had significant analysis of the contribution of practitioner knowledge to the assessment. However, the Kristianstad Wetlands (Sweden) assessment was structured so that practitioner knowledge was fully integrated within the assessment process. The Tropical Forest Margins assessment showed that, in the areas studied, practitioner knowledge has become more integrated over time as there have been intensive efforts to ensure stakeholder participation. Several other assessments encountered problems in utilizing practitioner knowledge, in many cases because practitioners were viewed as users of the assessment results instead of knowledge holders in their own right. Engagement of assessment users and other practitioners as knowledge holders requires more attention to how knowledge is used in policy-making, decision-making, and NGO and bureaucratic practice. [5]

The extent to which local and traditional ecological knowledge contributed to the assessments varied, due to local circumstances, the predisposition and expertise of the assessment team, and the resources allocated to understanding and using local knowledge. Local and traditional knowledge is both complex and inherently contextual, and a rigorous and comprehensive investigation and interpretation of such knowledge is needed to fully understand it and the insights it provides on ecosystem dynamics. Collaborative relationships, such as those developed in Vilcanota and Bajo Chirripó, as well as participatory tools that broaden the level of inquiry, often result in the emergence of key issues of local importance. For example, in the Bajo Chirripó assessment, local participants found that there was existing traditional knowledge about natural resource management strategies, so the assessment emphasized learning more about and reviving these instead of introducing new ones. [5]

The MA assumed that participation would empower local resource users in two ways. First, it would increase local ownership over the assessment process and results. Second, validation by scientists would cause decision-makers to recognize and use local knowledge. However, as local participation varied from fully collaborative to extractive, so too did the potential for empowerment. At one end of the spectrum was the Vilcanota assessment, in which local resource users designed and directed the assessment process with relatively less involvement and direction from scientists. Western China was at the opposite end: what local knowledge was used was inserted into a scientific framework where local and traditional knowledge was not central. [5]

The sharing of knowledge across scales in the sub-global assessments did not occur to the extent hoped for by the MA. This was partially due to methodological issues, such as uneven emphasis on different knowledge systems and difficulties with the validation of different forms

of knowledge. Procedures for the validation of local and traditional knowledge at the local level were adequately handled with the guidelines developed by the MA, but the sub-global assessments often lacked adequate processes of validation for the use of local knowledge at higher levels. Mediating institutions or boundary organizations are usually necessary for this, and these were not present for a number of the sub-global assessments. [5]

There is evidence that including multiple knowledge systems increases the relevance, credibility, and legitimacy of the assessment results for some users. For example, in Bajo Chirripó in Costa Rica, the involvement of non-scientists added legitimacy and relevance to assessment results for a number of potential assessment users at the local level. However, in many of the sub-global assessments, local resource users were only one among many groups of decision-makers, so the question of legitimacy needs to be taken together with that of empowerment. [5]

Some sub-global assessments confirmed that local institutions have a role in conferring greater power to local knowledge holders in cross-scale decision-making. For example, in India local and Kristianstad Wetlands (Sweden), deliberate efforts were made to embed the assessment within existing institutions that link local knowledge to higher-level decision-making processes. However, in the SAfMA Livelihoods assessment, local community institutions help to maintain knowledge, but by themselves were unable to ensure the use of local knowledge at higher-levels of decision-making. The Vilcanota and Bajo Chirripó assessments attempted to create space to begin a dialogue between local communities and decision-makers at higher scales. The success of these efforts can only be evaluated with more time. [5]

4. What Are the Important Lessons for Future Sub-global Assessments?

The MA conceptual framework served as a valuable tool and initial point of reference, but had to be adapted by some sub-global assessments.

Capturing the complex and dynamic nature of the interactions between ecosystems and humans required complementary conceptual frameworks in some contexts. Several community-based assessments adapted the MA framework to allow for more dynamic interplays between variables, capture fine-grained patterns and processes in complex systems, and leave room for a more spiritual worldview. In Peru and Costa Rica, for example, other conceptual frameworks were used that incorporated both the MA principles and local cosmologies. (See Figure SG5.) In southern Africa, various frameworks were used in parallel to offset the shortcomings of the MA framework for community assessments. These modifications and adaptations of the framework are an important outcome of the MA. [5, 11]

Capacity-building activities need to be an integral component of any assessment, but especially in a complex one such as the MA. Many sub-global assessments did not have the expertise to assess the various components of the MA conceptual framework, and there was a need to develop expertise through capacity-building activities. This included a need to develop methods to assess even the central tenet of the conceptual framework: the link between ecosystem services and human well-being. In addition to capacity-building activities initiated within assessments, the number and diversity of the assessments participating in the MA provided an ideal opportunity for capacity-building across the sub-global network. Networks formed among assessments became a way of exchanging experiences and methods and helped in the progress of some assessments. To fully incorporate multiple scales and knowledge systems in the design of all the sub-global assessments would have required more time and funding to develop the necessary tools and expertise. [6]

Multiscale assessments provide significant benefits, but they pose process and analytical challenges, are resource- and time-intensive, and, depending on assessment goals, may not always be necessary.

Both multiscale assessments and assessments incorporating multiscale analyses face analytical challenges not present in single-scale assessments. These challenges include: 1) the selection and measurement of ecosystem services and components of human well-being, and whether these should be consistent across scales; 2) determining the degree of nestedness; 3) establishing methods for cross-scale comparisons; and 4) ensuring information flow across the scales of the assessment. [4]

Multiscale assessments face additional challenges related to the most appropriate model for stakeholder involvement and participation. The presence of stakeholder groups from different scales, each with their own needs from the assessment and differing perceptions, can result in tension. Whereas a more rigid methodology and protocol may better meet analytical needs for multiscale analyses, a more flexible approach is often necessary to accommodate or adapt to different stakeholders from different scales. Thus design approaches for multiscale assessments vary depending on the requirements of analytical rigor and stakeholder involvement. [4]

Multiscale assessments are both resource- and time-intensive. These added costs may be justified when the goal is to inform and influence decisions, but a full multiscale assessment may not be necessary or desirable if the primary goal is only to formalize knowledge or to test the robustness of scientific findings. Sub-global assessments that were multiscale did obtain information benefits (improved assessment findings) related to the availability of more and better data, ground-truthing of data, and better analysis of the causes of change. However, many of these benefits could be as readily obtained (at lower cost) by

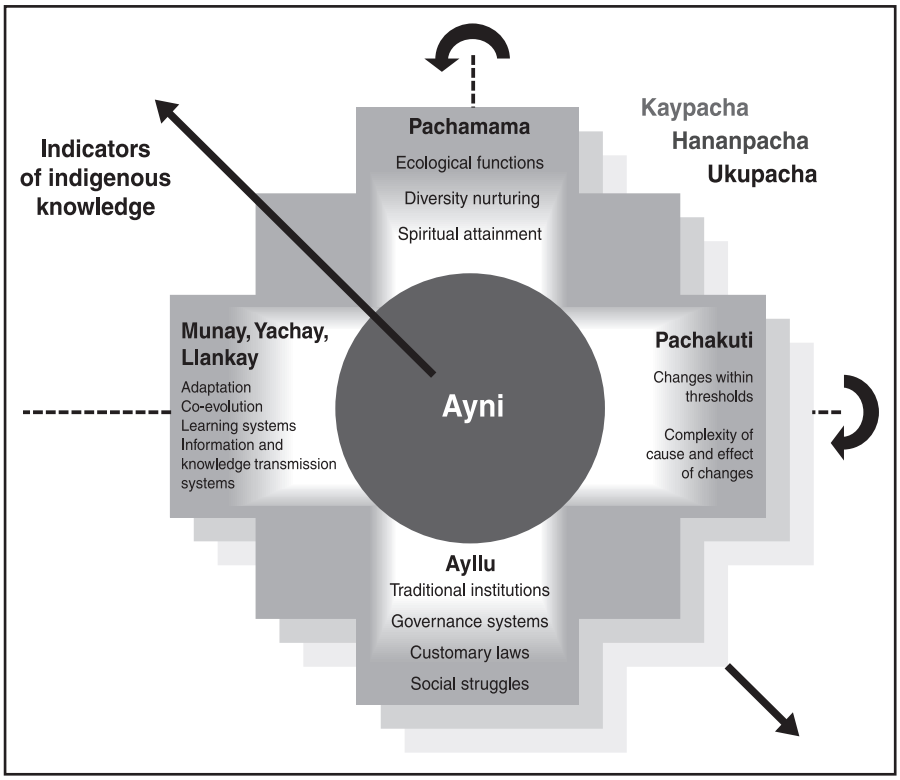


Figure SG5. Adapting the MA Conceptual Framework for Local Needs. The conceptual framework of the sub-global assessment in Vilcanota, Peru, was derived in part from the Inca cosmovision and in part from the MA conceptual framework, which was reinterpreted by the Quechua communities. The resulting framework has many similarities with the MA conceptual framework. The divergent features are considered to be highly important by the Quechua people conducting the assessment. Concepts such as reciprocity (*Ayni*), the inseparability of space and time, and the cyclical nature of all processes (*Pachakuti*) are important components of the Inca view of ecosystems. Love (*Munay*) and working (*Llankay*) bring humans to a higher state of knowledge *(Yachay)* about their surroundings, and are therefore key concepts linking Quechua communities to the natural world. *Ayllu* represents the governing institutions that regulate interactions among all living beings. *Kaypacha, Hananpacha,* and *Ukupacha* represent spatial scales and the cyclical relationship between the past, present, and future. Inherent in this concept of space and time is the adaptive capacity of the Quechua people, who welcome change and have become resilient to it. The Southern Cross shape of the Vilcanota conceptual framework diagram represents the *Chakana,* the most recognized and sacred shape to Quechua people. Chakana orders the world through deliberative and collective decision-making that emphasizes reciprocity (*Ayni*). *Pachamama* (the "mother earth," divinity, and place where past, present, and future coincide) is similar to the MA concept of ecosystem services combined with human well-being. Pachakuti is similar to the MA drivers (both direct and indirect). Ayllu (and Munay, Yachay, and Llankay) may be seen as responses, and are more organically integrated into the cyclic process of change and adaptation.

working fully at one or two scales while considering intermediate scales (multiscale analyses), rather than by conducting a full multiscale assessment. In contrast, a full multiscale design provided impact benefits associated with the use and adoption of the findings that could not be achieved through other approaches. The multiscale approach also increased the potential capacity of institutions and individuals involved to respond to changes in ecosystem services, even across existing political, national, and cultural boundaries (as in the case of SAfMA). [4]

For success, a sub-global assessment requires understanding of the context, adequate resources, champions and actively engaged users, and a governance structure able to manage competing needs.

The sub-global assessment process was dynamic and iterative. An assessment that links science with policy, such as the MA, provides a critical, objective evaluation and analysis of information, to meet user needs and support decision-making on complex issues. The three main stages of the assessment process were: an exploration stage, a design stage, and implementation of the resulting work plan, which included the review, validation, and communication of the findings. Throughout these stages, ongoing communication and user engagement permitted a flexible and iterative process, with some overlap between stages. (See Figure SG6.) [6]

Each sub-global assessment process was embedded in political, social, and environmental circumstances. The heterogeneity of these circumstances, as well as constraints such as the availability of information or particular expertise, necessitated a variety of approaches to using the MA conceptual framework. This reflects the reality of conducting integrated assessments at the sub-global level. An exploration of institutions that could potentially

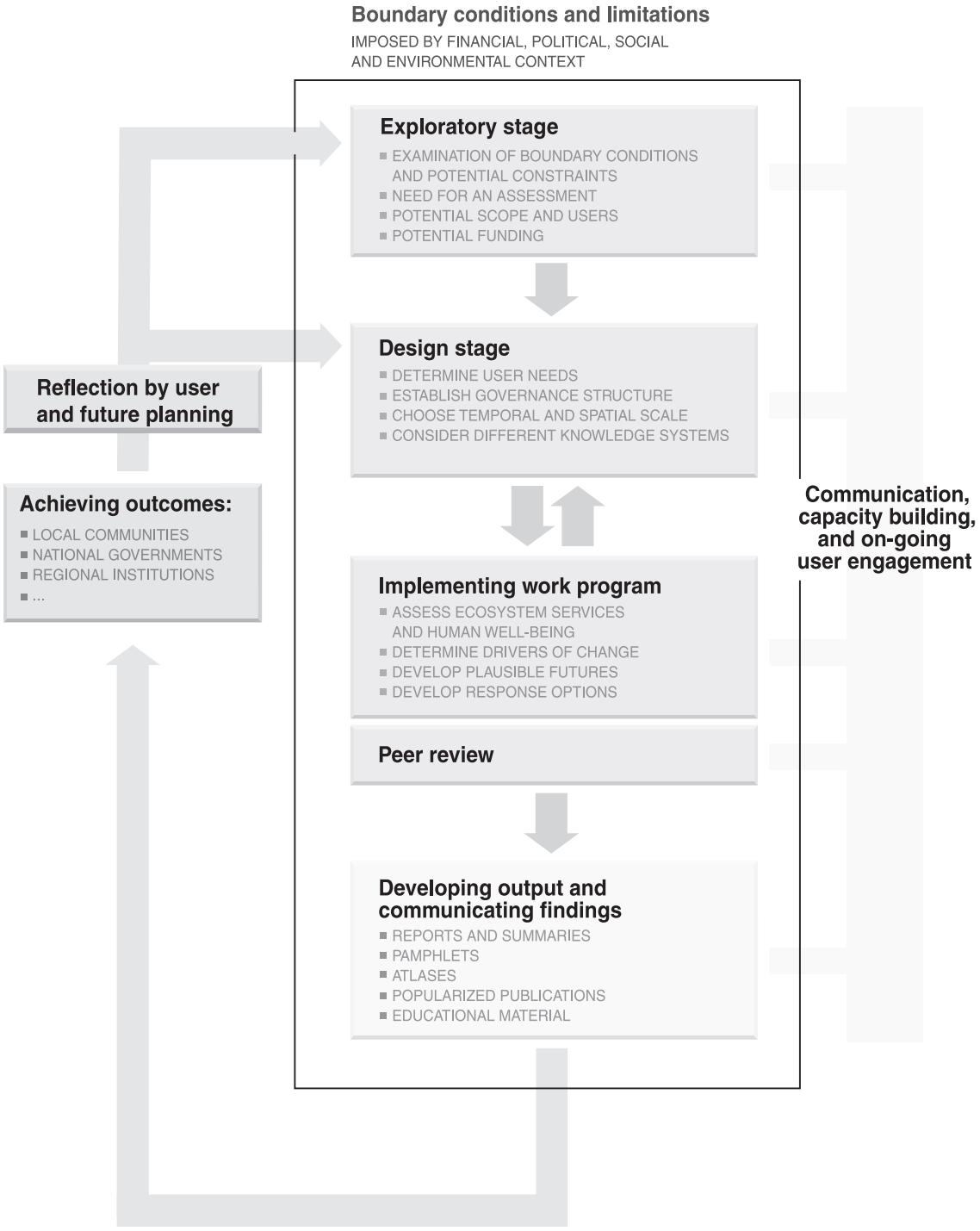


Figure SG6. The Sub-global Assessment Process

implement assessment outcomes should be included in the exploratory stages of the assessment. [6]

The sub-global assessments faced multiple constraints and had to overcome these challenges in order to make progress. Constraints included lack of data, limitations in financial support, and limited time. Further challenges included gaining the trust of different users, establishing and maintaining user engagement, securing technical leadership, and building the capacity to conduct multiscale, integrated assessments. These constraints limited the scope of the sub-global assessments in terms of the number of ecosystem services and aspects of human well-being that were included, the temporal and spatial scales considered, and the knowledge systems incorporated. Sub-global assessments that incorporated different knowledge systems required more time and resources to be set aside to support innovative work on these aspects. [6]

Assessments need champions. In many cases, specific individuals played key roles that were critical for providing the needed momentum and direction during different stages of an assessment. These roles include that of external facilitators who helped to establish the demand for an assessment,

and leadership to guide and sustain the assessment process. In some cases, small dedicated teams of people championed the assessment together. [6]

The groups that will use the assessment results must be involved throughout the entire assessment process, from the design of the assessment through to the communication of findings. Working with assessment users to identify processes that would use the assessment findings was essential, as it was an important part of establishing the demand for an assessment. The sub-global assessments responded to three broad categories of need for an assessment: (1) summary and synthesis of information on complex issues to support decision-making; (2) strengthening the capacity of the users to assess and manage their resources or to participate in resource management; (3) research to address gaps in knowledge for resource management. For the first two categories in particular, the assessments involved strong user engagement throughout the process. [6]

A governance structure that provided a forum for discussion was necessary in assessments that involved a wide range of users. Many sub-global assessments considered diverse user needs and needed to manage the tensions between them, as well as allocation of resources for competing needs. This included prioritizing the components of the MA conceptual framework to be addressed. [6]

The sub-global assessment process has generated new tools and methodologies and baseline information that have helped to empower stakeholders; more products and outcomes will come to fruition in the future.

The sub-global assessments have yielded a number of tangible outcomes. Most global assessments, including the global component of the MA, have focused on producing synthetic reports, with their findings as the main outcome. In this regard, the final reports from individual sub-global assessments (or, for those assessments still in progress at the time this volume was written, peer-reviewed 30-page summaries) are a comparable result. Each of these assessments contains a wealth of information regarding the condition of ecosystem services, scenarios, and response options, each focused and shaped by the circumstances and needs of their particular setting. In addition, this volume aims to provide an overview of the sub-global process, with some comparisons and emerging patterns observed to date.

The sub-global assessment process has catalyzed the development of new tools and methodologies, the collation and generation of baseline information, and the creation of governance mechanisms that empower stakeholders. The constraints faced by the sub-global assessments sometimes led to innovative approaches to overcoming these constraints. Examples include the development of a novel biodiversity intactness index by the Southern Africa Regional assessment, and the training of technicians and video operators in the Peruvian Andes to lead and document the assessment of soil, water and agrobiodiversity by community groups. Another example was the advisory group of the San Pedro de Atacama assessment in Chile—which brought together different stakeholder groups to discuss ecosystem management for human well-being, for the first time. [12]

Some important results from the sub-global assessments are less tangible, and are primarily related to capacity-building. These include the capacities that were developed to lead and undertake similar, and improved, assessments in the future. These capacities will be reinforced by the network of institutions and professionals that has been developed in the course of the MA. One example was the development of a fellowship program for younger scientists, many of whom went on to work closely with the Coordinating Lead Authors of this assessment volume.

The value added by sub-global assessment processes in the future can be increased. In doing so, the following tradeoffs should be taken into consideration:

- a rigorous approach to selecting assessments will ensure better geographical coverage and representation of ecosystems, but this should be weighed against the benefits of more innovation, diversity and strong user demand that arise from a bottom-up selection process;
- fully nested, multiscale assessments will deliver significant information and impact benefits, but may not always be necessary, especially in the light of the substantial resources and capacity required to undertake them; and
- focusing on a small set of services in common across all sub-global assessments will facilitate greater comparability, but the diverse circumstances and priorities of individual assessments may necessitate flexibility and a less rigidly uniform analytical approach.

A number of important additional considerations for future sub-global assessments would include:

- ensuring the availability of essential training and capacity-building, and tools and methodologies, especially in areas like developing scenarios and multiscale approaches to assessment;
- fostering continued interdisciplinary approaches involving both natural and social scientists, to comprehensively analyze the links between ecosystem services and human well-being; and
- sufficient funding for the full set of assessment activities planned.

Some of the most important results of the sub-global assessment process are yet to come. The existing sub-global assessments are at very different stages of implementation, ranging from completed assessment to those in their early stages. It is important to build on the experience gained so far and to continue the existing network. This will also enable a better assessment of the real impact of the process on the management of ecosystems for human well-being. [12]

Chapter 1

MA Conceptual Framework

Main Messages *16*

1.1 Introduction **16**

1.2 What Is the Problem? **17**

1.3 Conceptual Framework **19**
1.3.1 Ecosystems and Their Services
1.3.2 Human Well-being and Poverty Reduction
1.3.3 Drivers of Change
1.3.4 Cross-scale Interactions and Assessment

1.4 Values Associated with Ecosystems **24**

1.5 Assessment Tools **25**

1.6 Strategies and Interventions **26**

BOXES

1.1 Key Definitions
1.2 Millennium Ecosystem Assessment Conceptual Framework
1.3 Reporting Categories Used in the Millennium Ecosystem Assessment
1.4 Valuation of Ecosystem Services

FIGURES

1.1 Linkages between Ecosystem Services and Human Well-being

This chapter provides the summary of Millennium Ecosystem Assessment, *Ecosystems and Human Well-being: A Framework for Assessment* (Island Press, 2003), pp. 1–25, which was prepared by an extended conceptual framework writing team of 51 authors and 10 contributing authors.

Main Messages

Human well-being and progress toward sustainable development are vitally dependent upon improving the management of Earth's ecosystems to ensure their conservation and sustainable use. But while demands for ecosystem services such as food and clean water are growing, human actions are at the same time diminishing the capability of many ecosystems to meet these demands.

Sound policy and management interventions can often reverse ecosystem degradation and enhance the contributions of ecosystems to human well-being, but knowing when and how to intervene requires substantial understanding of both the ecological and the social systems involved. Better information cannot guarantee improved decisions, but it is a prerequisite for sound decision-making.

The Millennium Ecosystem Assessment was established to help provide the knowledge base for improved decisions and to build capacity for analyzing and supplying this information.

This chapter presents the conceptual and methodological approach that the MA used to assess options that can enhance the contribution of ecosystems to human well-being. This same approach should provide a suitable basis for governments, the private sector, and civil society to factor considerations of ecosystems and ecosystem services into their own planning and actions.

1.1 Introduction

Humanity has always depended on the services provided by the biosphere and its ecosystems. Further, the biosphere is itself the product of life on Earth. The composition of the atmosphere and soil, the cycling of elements through air and waterways, and many other ecological assets are all the result of living processes—and all are maintained and replenished by living ecosystems. The human species, while buffered against environmental immediacies by culture and technology, is ultimately fully dependent on the flow of ecosystem services.

In his April 2000 Millennium Report to the United Nations General Assembly, in recognition of the growing burden that degraded ecosystems are placing on human well-being and economic development and the opportunity that better managed ecosystems provide for meeting the goals of poverty eradication and sustainable development, United Nations Secretary-General Kofi Annan stated that:

> *It is impossible to devise effective environmental policy unless it is based on sound scientific information. While major advances in data collection have been made in many areas, large gaps in our knowledge remain. In particular, there has never been a comprehensive global assessment of the world's major ecosystems. The planned Millennium Ecosystem Assessment, a major international collaborative effort to map the health of our planet, is a response to this need.*

The Millennium Ecosystem Assessment was established with the involvement of governments, the private sector, nongovernmental organizations, and scientists to provide an integrated assessment of the consequences of ecosystem change for human well-being and to analyze options available to enhance the conservation of ecosystems and their contributions to meeting human needs. The Convention on Biological Diversity, the Convention to Combat Desertification, the Convention on Migratory Species, and the Ramsar Convention on Wetlands plan to use the findings of the MA, which will also help meet the needs of others in government, the private sector, and civil society. The MA should help to achieve the United Nations Millennium Development Goals and to carry out the Plan of Implementation of the 2002 World Summit on Sustainable Development. It has mobilized hundreds of scientists from countries around the world to provide information and clarify science concerning issues of greatest relevance to decision-makers. The MA has identified areas of broad scientific agreement and also pointed to areas of continuing scientific debate.

The assessment framework developed for the MA offers decision-makers a mechanism to:

- ***Identify options that can better achieve core human development and sustainability goals. All countries and communities are grappling with the challenge of meeting growing demands for food, clean water, health, and employment.*** And decision-makers in the private and public sectors must also balance economic growth and social development with the need for environmental conservation. All of these concerns are linked directly or indirectly to the world's ecosystems. The MA process, at all scales, was designed to bring the best science to bear on the needs of decision-makers concerning these links between ecosystems, human development, and sustainability.
- ***Better understand the trade-offs involved—across sectors and stakeholders—in decisions concerning the environment.*** Ecosystem-related problems have historically been approached issue by issue, but rarely by pursuing multisectoral objectives. This approach has not withstood the test of time. Progress toward one objective such as increasing food production has often been at the cost of progress toward other objectives such as conserving biological diversity or improving water quality. The MA framework complements sectoral assessments with information on the full impact of potential policy choices across sectors and stakeholders.
- ***Align response options with the level of governance where they can be most effective.*** Effective management of ecosystems will require actions at all scales, from the local to the global. Human actions now directly or inadvertently affect virtually all of the world's ecosystems; actions required for the management of ecosystems refer to the steps that humans can take to modify their direct or indirect influences on ecosystems. The management and policy options available and the concerns of stakeholders differ greatly across these scales. The priority areas for biodiversity conservation in a country as defined based on "global" value, for example, would be very different from those as defined based on the value to local communities. The multiscale assessment framework developed for the MA provides a new approach for analyzing

policy options at all scales—from local communities to international conventions.

1.2 What Is the Problem?

Ecosystem services are the benefits people obtain from ecosystems, which the MA describes as provisioning, regulating, supporting, and cultural services. (See Box 1.1.) Ecosystem services include products such as food, fuel, and fiber; regulating services such as climate regulation and disease control; and nonmaterial benefits such as spiritual or aesthetic benefits. Changes in these services affect human well-being in many ways. (See Figure 1.1.)

The demand for ecosystem services is now so great that trade-offs among services have become the rule. A country can increase food supply by converting a forest to agriculture, for example, but in so doing it decreases the supply of services that may be of equal or greater importance, such as clean water, timber, ecotourism destinations, or flood regulation and drought control. There are many indications that human demands on ecosystems will grow still greater in the coming decades. Current estimates of 3 billion more people and a quadrupling of the world economy by 2050 imply a formidable increase in demand for and consumption of biological and physical resources, as well as escalating impacts on ecosystems and the services they provide.

The problem posed by the growing demand for ecosystem services is compounded by increasingly serious degradation in the capability of ecosystems to provide these services. World fisheries are now declining due to overfishing, for instance, and a significant amount of agricultural land has been degraded in the past half-century by erosion, salinization, compaction, nutrient depletion, pollution, and urbanization. Other human-induced impacts on ecosystems include alteration of the nitrogen, phosphorous, sulfur, and carbon cycles, causing acid rain, algal blooms, and fish kills in rivers and coastal waters, along with contributions to climate change. In many parts of the world, this degradation of ecosystem services is exacerbated by the associated loss of the knowledge and understanding held by local communities—knowledge that sometimes could help to ensure the sustainable use of the ecosystem.

This combination of ever-growing demands being placed on increasingly degraded ecosystems seriously diminishes the prospects for sustainable development. Human well-being is affected not just by gaps between ecosystem service supply and demand but also by the increased vulnerability of individuals, communities, and nations. Productive ecosystems, with their array of services, provide people and communities with resources and options they can use as insurance in the face of natural catastrophes or social upheaval. While well-managed ecosystems reduce risks and vulnerability, poorly managed systems can exacerbate them by increasing risks of flood, drought, crop failure, or disease.

Ecosystem degradation tends to harm rural populations more directly than urban populations and has its most direct and severe impact on poor people. The wealthy control access to a greater share of ecosystem services, consume those services at a higher per capita rate, and are buffered from changes in their availability (often at a substantial cost) through their ability to purchase scarce ecosystem services or substitutes. For example, even though a number of marine fisheries have been depleted in the past century, the supply of fish to wealthy consumers has not been disrupted since fishing fleets have been able to shift to previously underexploited stocks. In contrast, poor people often lack access to alternate services and are highly vulnerable to ecosystem changes that result in famine, drought, or floods. They frequently live in locations particularly sensitive to environmental threats, and they lack financial and institutional buffers against these dangers. Degradation of coastal fishery resources, for instance, results in a decline in protein consumed by the local community since fishers may not have access to alternate sources of fish and community members may not have enough income to purchase fish. Degradation affects their very survival.

Changes in ecosystems affect not just humans but countless other species as well. The management objectives that people set for ecosystems and the actions that they take are influenced not just by the consequences of ecosystem changes for humans but also by the importance people place on considerations of the intrinsic value of species and ecosystems. Intrinsic value is the value of something in and for itself, irrespective of its utility for someone else. For example, villages in India protect ''spirit sanctuaries'' in relatively natural states, even though a strict cost-benefit calculation might favor their conversion to agriculture. Similarly, many countries have passed laws protecting endangered species based on the view that these species have a right to exist, even if their protection results in net economic costs. Sound ecosystem management thus involves steps to address the utilitarian links of people to ecosystems as well as processes that allow considerations of the intrinsic value of ecosystems to be factored into decision-making.

BOX 1.1
Key Definitions

Ecosystem. An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. Humans are an integral part of ecosystems. Ecosystems vary enormously in size; a temporary pond in a tree hollow and an ocean basin can both be ecosystems.

Ecosystem services. Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits.

Well-being. Human well-being has multiple constituents, including basic material for a good life, freedom of choice and action, health, good social relations, and security. Well-being is at the opposite end of a continuum from poverty, which has been defined as a "pronounced deprivation in well-being." The constituents of well-being, as experienced and perceived by people, are situation-dependent, reflecting local geography, culture, and ecological circumstances.

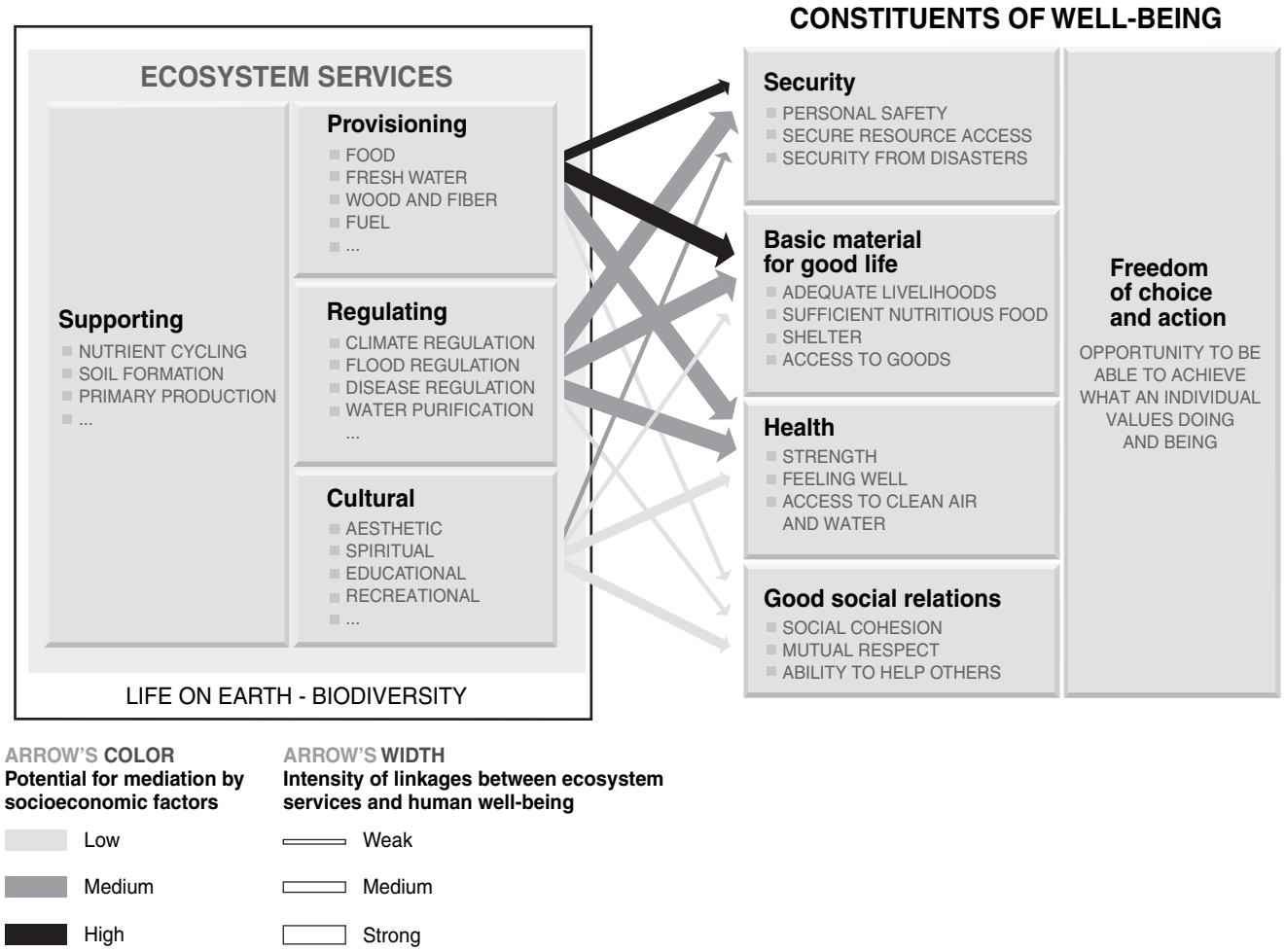


Figure 1.1. Linkages between Ecosystem Services and Human Well-being. This Figure depicts the strength of linkages between categories of ecosystem services and components of human well-being that are commonly encountered and includes indications of the extent to which it is possible for socioeconomic factors to mediate the linkage. (For example, if it is possible to purchase a substitute for a degraded ecosystem service, then there is a high potential for mediation.) The strength of the linkages and the potential for mediation differ in different ecosystems and regions. In addition to the influence of ecosystem services on human well-being depicted here, other factors—including other environmental factors as well as economic, social, technological, and cultural factors—influence human well-being, and ecosystems are in turn affected by changes in human well-being. (Millennium Ecosystem Assessment)

The degradation of ecosystem services has many causes, including excessive demand for ecosystem services stemming from economic growth, demographic changes, and individual choices. Market mechanisms do not always ensure the conservation of ecosystem services either because markets do not exist for services such as cultural or regulatory services or, where they do exist, because policies and institutions do not enable people living within the ecosystem to benefit from services it may provide to others who are far away. For example, institutions are now only beginning to be developed to enable those benefiting from carbon sequestration to provide local managers with an economic incentive to leave a forest uncut, while strong economic incentives often exist for managers to harvest the forest. Also, even if a market exists for an ecosystem service, the results obtained through the market may be socially or ecologically undesirable. Properly managed, the creation of ecotourism opportunities in a country can create strong economic incentives for the maintenance of the cultural services provided by ecosystems, but poorly managed ecotourism activities can degrade the very resource on which they depend. Finally, markets are often unable to address important intra- and intergenerational equity issues associated with managing ecosystems for this and future generations, given that some changes in ecosystem services are irreversible.

The world has witnessed in recent decades not just dramatic changes to ecosystems but equally profound changes to social systems that shape both the pressures on ecosystems and the opportunities to respond. The relative influence of individual nation-states has diminished with the growth of power and influence of a far more complex array of institutions, including regional governments, multinational companies, the United Nations, and civil society organizations. Stakeholders have become more involved in decision-making. Given the multiple actors whose decisions now strongly influence ecosystems, the challenge of providing information to decision-makers has grown. At the same

time, the new institutional landscape may provide an unprecedented opportunity for information concerning ecosystems to make a major difference. Improvements in ecosystem management to enhance human well-being will require new institutional and policy arrangements and changes in rights and access to resources that may be more possible today under these conditions of rapid social change than they have ever been before.

Like the benefits of increased education or improved governance, the protection, restoration, and enhancement of ecosystem services tends to have multiple and synergistic benefits. Already, many governments are beginning to recognize the need for more effective management of these basic life-support systems. Examples of significant progress toward sustainable management of biological resources can also be found in civil society, in indigenous and local communities, and in the private sector.

1.3 Conceptual Framework

The conceptual framework for the MA places human well-being as the central focus for assessment, while recognizing that biodiversity and ecosystems also have intrinsic value and that people take decisions concerning ecosystems based on considerations of well-being as well as intrinsic value. (See Box 1.2.) The MA conceptual framework assumes that a dynamic interaction exists between people and other parts of ecosystems, with the changing human condition serving to both directly and indirectly drive change in ecosystems and with changes in ecosystems causing changes in human well-being. At the same time, many other factors independent of the environment change the human condition, and many natural forces are influencing ecosystems.

The MA focuses particular attention on the linkages between ecosystem services and human well-being. The assessment deals with the full range of ecosystems—from those relatively undisturbed, such as natural forests, to landscapes with mixed patterns of human use and ecosystems intensively managed and modified by humans, such as agricultural land and urban areas.

A full assessment of the interactions between people and ecosystems requires a multiscale approach because it better reflects the multiscale nature of decision-making, allows the examination of driving forces that may be exogenous to particular regions, and provides a means of examining the differential impact of ecosystem changes and policy responses on different regions and groups within regions.

This section explains in greater detail the characteristics of each of the components of the MA conceptual framework, moving clockwise from the lower left corner of the Figure in Box 1.2.

1.3.1 Ecosystems and Their Services

An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. Humans are an integral part of ecosystems. Ecosystems provide a variety of benefits to people, including provisioning, regulating, cultural, and supporting services. Provisioning services are the products people obtain from ecosystems, such as food, fuel, fiber, fresh water, and genetic resources. Regulating services are the benefits people obtain from the regulation of ecosystem processes, including air quality maintenance, climate regulation, erosion control, regulation of human diseases, and water purification. Cultural services are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences. Supporting services are those that are necessary for the production of all other ecosystem services, such as primary production, production of oxygen, and soil formation.

Biodiversity and ecosystems are closely related concepts. Biodiversity is the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part. It includes diversity within and between species and diversity of ecosystems. Diversity is a structural feature of ecosystems, and the variability among ecosystems is an element of biodiversity. Products of biodiversity include many of the services produced by ecosystems (such as food and genetic resources), and changes in biodiversity can influence all the other services they provide. In addition to the important role of biodiversity in providing ecosystem services, the diversity of living species has intrinsic value independent of any human concern.

The concept of an ecosystem provides a valuable framework for analyzing and acting on the linkages between people and the environment. For that reason, the ''ecosystem approach'' has been endorsed by the Convention on Biological Diversity, and the MA conceptual framework is entirely consistent with this approach. The CBD states that the ecosystem approach is a strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way. This approach recognizes that humans, with their cultural diversity, are an integral component of many ecosystems.

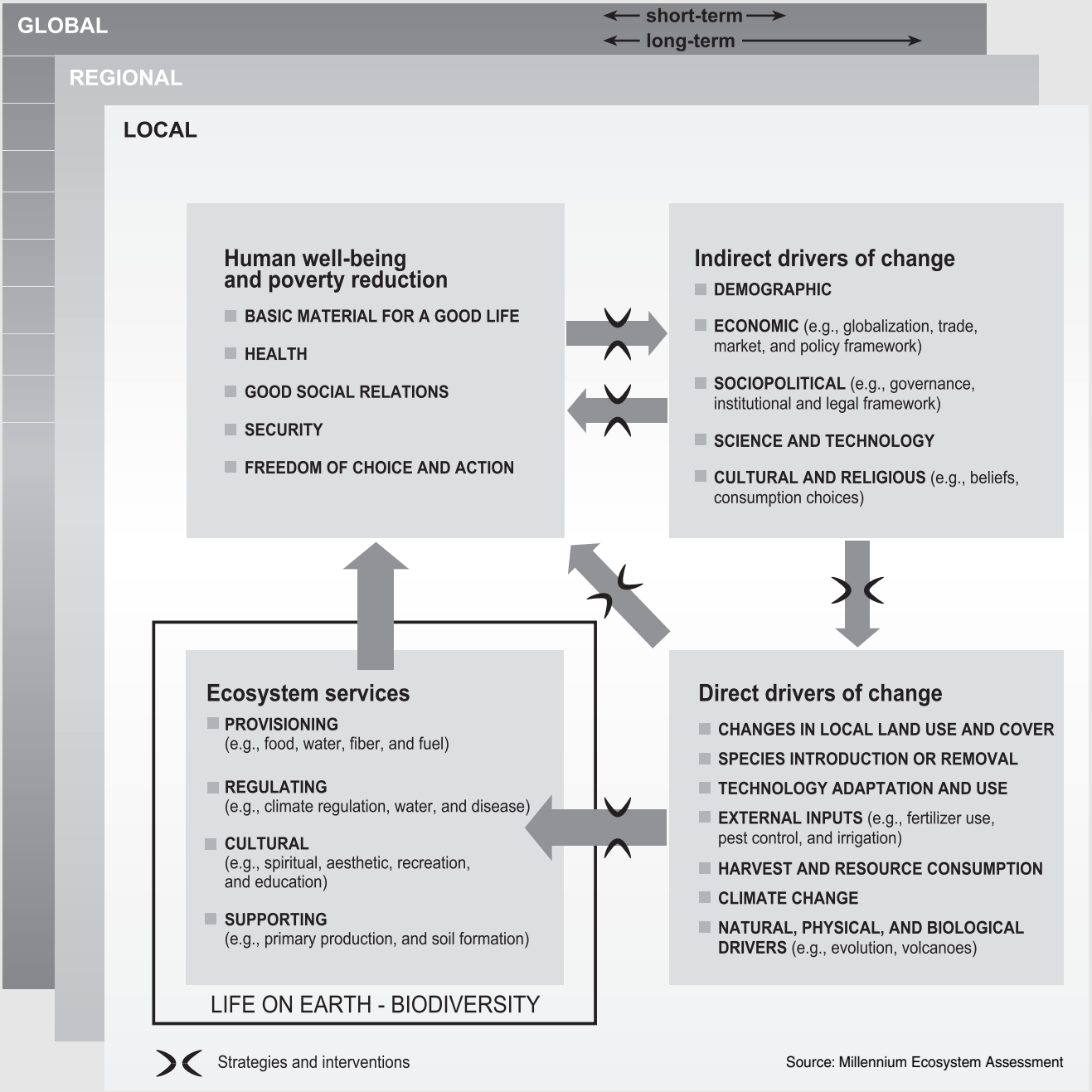
In order to implement the ecosystem approach, decision-makers need to understand the multiple effects on an ecosystem of any management or policy change. By way of analogy, decision-makers would not make a decision about financial policy in a country without examining the condition of the economic system, since information on the economy of a single sector such as manufacturing would be insufficient. The same need to examine the consequences of changes for multiple sectors applies to ecosystems. For instance, subsidies for fertilizer use may increase food production, but sound decisions also require information on whether the potential reduction in the harvests of downstream fisheries as a result of water quality degradation from the fertilizer runoff might outweigh those benefits.

For the purpose of analysis and assessment, a pragmatic view of ecosystem boundaries must be adopted, depending on the questions being asked. A well-defined ecosystem has strong interactions among its components and weak interactions across its boundaries. A useful choice of ecosystem boundary is one where a number of discontinuities coincide, such as in the distribution of organisms, soil types,

BOX 1.2

Millennium Ecosystem Assessment Conceptual Framework

Changes in factors that indirectly affect ecosystems, such as population, technology, and lifestyle (upper right corner of figure), can lead to changes in factors directly affecting ecosystems, such as the catch of fisheries or the application of fertilizers to increase food production (lower right corner). The resulting changes in the ecosystem (lower left corner) cause the ecosystem services to change and thereby affect human well-being. These interactions can take place at more than one scale and can cross scales. For example, a global market may lead to regional loss of forest cover, which increases flood magnitude along a local stretch of a river. Similarly, the interactions can take place across different time scales. Actions can be taken either to respond to negative changes or to enhance positive changes at almost all points in this framework (black cross bars).


GLOBAL
short-term
long-term
REGIONAL
LOCAL
Human well-being and poverty reduction
BASIC MATERIAL FOR A GOOD LIFE
HEALTH
GOOD SOCIAL RELATIONS
SECURITY
FREEDOM OF CHOICE AND ACTION
Indirect drivers of change
DEMOGRAPHIC
ECONOMIC (e.g., globalization, trade, market, and policy framework)
SOCIOPOLITICAL (e.g., governance, institutional and legal framework)
SCIENCE AND TECHNOLOGY
CULTURAL AND RELIGIOUS (e.g., beliefs, consumption choices)
Ecosystem services
PROVISIONING (e.g., food, water, fiber, and fuel)
REGULATING (e.g., climate regulation, water, and disease)
CULTURAL (e.g., spiritual, aesthetic, recreation, and education)
SUPPORTING (e.g., primary production, and soil formation)
LIFE ON EARTH - BIODIVERSITY
Direct drivers of change
CHANGES IN LOCAL LAND USE AND COVER
SPECIES INTRODUCTION OR REMOVAL
TECHNOLOGY ADAPTATION AND USE
EXTERNAL INPUTS (e.g., fertilizer use, pest control, and irrigation)
HARVEST AND RESOURCE CONSUMPTION
CLIMATE CHANGE
NATURAL, PHYSICAL, AND BIOLOGICAL DRIVERS (e.g., evolution, volcanoes)
Strategies and interventions
Source: Millennium Ecosystem Assessment

drainage basins, and depth in a waterbody. At a larger scale, regional and even globally distributed ecosystems can be evaluated based on a commonality of basic structural units. The global assessment being undertaken by the MA reports on marine, coastal, inland water, forest, dryland, island, mountain, polar, cultivated, and urban regions. These regions are not ecosystems themselves, but each contains a number of ecosystems. (See Box 1.3.)

People seek multiple services from ecosystems and thus perceive the condition of given ecosystems in relation to their ability to provide the services desired. Various methods can be used to assess the ability of ecosystems to deliver

BOX 1.3

Reporting Categories Used in the Millennium Ecosystem Assessment

The MA used 10 categories of systems to report its global findings. (See Table.) These categories are not ecosystems themselves; each contains a number of ecosystems. The MA reporting categories are not mutually exclusive: their areas can and do overlap. Ecosystems within each category share a suite of biological, climatic, and social factors that tend to differ across categories. Because these reporting categories overlap, any place on Earth may fall into more than one category. Thus, for example, a wetland ecosystem in a coastal region may be examined both in the MA analysis of "coastal systems" as well as in its analysis of "inland water systems."

Millennium Ecosystem Assessment Reporting Categories

Category	Central Concept	Boundary Limits for Mapping
Marine	Ocean, with fishing typically a major driver of change	Marine areas where the sea is deeper than 50 meters.
Coastal	Interface between ocean and land, extending seawards to about the middle of the continental shelf and inland to include all areas strongly influenced by the proximity to the ocean	Area between 50 meters below mean sea level and 50 meters above the high tide level or extending landward to a distance 100 kilometers from shore. Includes coral reefs, intertidal zones, estuaries, coastal aquaculture, and seagrass communities.
Inland water	Permanent water bodies inland from the coastal zone, and areas whose ecology and use are dominated by the permanent, seasonal, or intermittent occurrence of flooded conditions	Rivers, lakes, floodplains, reservoirs, and wetlands; includes inland saline systems. Note that the Ramsar Convention considers "wetlands" to include both inland water and coastal categories.
Forest	Lands dominated by trees; often used for timber, fuelwood, and non-timber forest products	A canopy cover of at least 40% by woody plants taller than 5 meters. The existence of many other definitions is acknowledged, and other limits (such as crown cover greater than 10%, as used by the Food and Agriculture Organization of the United Nations) are also reported. Includes temporarily cut-over forests and plantations; excludes orchards and agroforests where the main products are food crops.
Dryland	Lands where plant production is limited by water availability; the dominant uses are large mammal herbivory, including livestock grazing, and cultivation	Drylands as defined by the Convention to Combat Desertification, namely lands where annual precipitation is less than two thirds of potential evaporation, from dry subhumid areas (ratio ranges 0.50–0.65), through semiarid, arid, and hyper-arid (ratio <0.05), but excluding polar areas; drylands include cultivated lands, scrublands, shrublands, grasslands, semi-deserts, and true deserts.
Island	Lands isolated by surrounding water, with a high proportion of coast to hinterland	Islands of at least 1.5 hectares included in the ESRI ArcWorld Country Boundary dataset.
Mountain	Steep and high lands	As defined by Mountain Watch using criteria based on elevation alone, and at lower elevation, on a combination of elevation, slope, and local elevation range. Specifically, elevation $>2,500$ meters, elevation 1,500–2,500 meters and slope >2 degrees, elevation 1,000–1,500 meters and slope >5 degrees or local elevation range (7 kilometers radius) >300 meters, elevation 300–1,000 meters and local elevation range (7 kilometers radius) >300 meters, isolated inner basins and plateaus less than 25 square kilometers extent that are surrounded by mountains.
Polar	High-latitude systems frozen for most of the year	Includes ice caps, areas underlain by permafrost, tundra, polar deserts, and polar coastal areas. Excludes high-altitude cold systems in low latitudes.
Cultivated	Lands dominated by domesticated plant species, used for and substantially changed by crop, agroforestry, or aquaculture production	Areas in which at least 30% of the landscape comes under cultivation in any particular year. Includes orchards, agroforestry, and integrated agriculture-aquaculture systems.
Urban	Built environments with a high human density	Known human settlements with a population of 5,000 or more, with boundaries delineated by observing persistent night-time lights or by inferring areal extent in the cases where such observations are absent.

particular services. With those answers in hand, stakeholders have the information they need to decide on a mix of services best meeting their needs. The MA considers criteria and methods to provide an integrated view of the condition of ecosystems. The condition of each category of ecosystem services is evaluated in somewhat different ways, although in general a full assessment of any service requires considerations of stocks, flows, and resilience of the service.

1.3.2 Human Well-being and Poverty Reduction

Human well-being has multiple constituents, including the basic material for a good life, freedom of choice and action, health, good social relations, and security. Poverty is also multidimensional and has been defined as the pronounced deprivation of well-being. How well-being, ill-being, or poverty are experienced and expressed depends on context and situation, reflecting local physical, social, and personal factors such as geography, environment, age, gender, and culture. In all contexts, however, ecosystems are essential for human well-being through their provisioning, regulating, cultural, and supporting services.

Human intervention in ecosystems can amplify the benefits to human society. However, evidence in recent decades of escalating human impacts on ecological systems worldwide raises concerns about the spatial and temporal consequences of ecosystem changes detrimental to human well-being. Ecosystem changes affect human well-being in the following ways:

- ***Security*** is affected both by changes in provisioning services, which affect supplies of food and other goods and the likelihood of conflict over declining resources, and by changes in regulating services, which could influence the frequency and magnitude of floods, droughts, landslides, or other catastrophes. It can also be affected by changes in cultural services as, for example, when the loss of important ceremonial or spiritual attributes of ecosystems contributes to the weakening of social relations in a community. These changes in turn affect material well-being, health, freedom and choice, security, and good social relations.
- ***Access to basic material for a good life*** is strongly linked to both provisioning services such as food and fiber production and regulating services, including water purification.
- ***Health*** is strongly linked to both provisioning services such as food production and regulating services, including those that influence the distribution of disease-transmitting insects and of irritants and pathogens in water and air. Health can also be linked to cultural services through recreational and spiritual benefits.
- ***Social relations*** are affected by changes to cultural services, which affect the quality of human experience.
- ***Freedom of choice and action*** is largely predicated on the existence of the other components of well-being and are thus influenced by changes in provisioning, regulating, or cultural services from ecosystems.

Human well-being can be enhanced through sustainable human interactions with ecosystems supported by necessary instruments, institutions, organizations, and technology. Creation of these through participation and transparency may contribute to freedoms and choice as well as to increased economic, social, and ecological security. By ecological security, we mean the minimum level of ecological stock needed to ensure a sustainable flow of ecosystem services.

Yet the benefits conferred by institutions and technology are neither automatic nor equally shared. In particular, such opportunities are more readily grasped by richer than poorer countries and people; some institutions and technologies mask or exacerbate environmental problems; responsible governance, while essential, is not easily achieved; participation in decision-making, an essential element of responsible governance, is expensive in time and resources to maintain. Unequal access to ecosystem services has often elevated the well-being of small segments of the population at the expense of others.

Sometimes the consequences of the depletion and degradation of ecosystem services can be mitigated by the substitution of knowledge and of manufactured or human capital. For example, the addition of fertilizer in agricultural systems has been able to offset declining soil fertility in many regions of the world where people have sufficient economic resources to purchase these inputs, and water treatment facilities can sometimes substitute for the role of watersheds and wetlands in water purification. But ecosystems are complex and dynamic systems and there are limits to substitution possibilities, especially with regulating, cultural, and supporting services. No substitution is possible for the extinction of culturally important species such as tigers or whales, for instance, and substitutions may be economically impractical for the loss of services such as erosion control or climate regulation. Moreover, the scope for substitutions varies by social, economic, and cultural conditions. For some people, especially the poorest, substitutes and choices are very limited. For those who are better off, substitution may be possible through trade, investment, and technology.

Because of the inertia in both ecological and human systems, the consequences of ecosystem changes made today may not be felt for decades. Thus, sustaining ecosystem services, and thereby human well-being, requires a full understanding and wise management of the relationships between human activities, ecosystem change, and well-being over the short, medium, and long term. Excessive current use of ecosystem services compromises their future availability. This can be prevented by ensuring that the use is sustainable.

Achieving sustainable use requires effective and efficient institutions that can provide the mechanisms through which concepts of freedom, justice, fairness, basic capabilities, and equity govern the access to and use of ecosystem services. Such institutions may also need to mediate conflicts between individual and social interests that arise.

The best way to manage ecosystems to enhance human well-being will differ if the focus is on meeting needs of the poor and weak or the rich and powerful. For both groups, ensuring the long-term supply of ecosystem services is es-

sential. But for the poor, an equally critical need is to provide more equitable and secure access to ecosystem services.

1.3.3 Drivers of Change

Understanding the factors that cause changes in ecosystems and ecosystem services is essential to designing interventions that capture positive impacts and minimize negative ones. In the MA, a ''driver'' is any factor that changes an aspect of an ecosystem. A direct driver unequivocally influences ecosystem processes and can therefore be identified and measured to differing degrees of accuracy. An indirect driver operates more diffusely, often by altering one or more direct drivers, and its influence is established by understanding its effect on a direct driver. Both indirect and direct drivers often operate synergistically. Changes in land cover, for example, can increase the likelihood of introduction of alien invasive species. Similarly, technological advances can increase rates of economic growth.

The MA explicitly recognizes the role of decision-makers who affect ecosystems, ecosystem services, and human well-being. Decisions are made at three organizational levels, although the distinction between those levels is often diffuse and difficult to define:

- by individuals and small groups at the local level (such as a field or forest stand) who directly alter some part of the ecosystem;
- by public and private decision-makers at the municipal, provincial, and national levels; and
- by public and private decision-makers at the international level, such as through international conventions and multilateral agreements.

The decision-making process is complex and multidimensional. We refer to a driver that can be influenced by a decision-maker as an endogenous driver and one over which the decision-maker does not have control as an exogenous driver. The amount of fertilizer applied on a farm is an endogenous driver from the standpoint of the farmer, for example, while the price of the fertilizer is an exogenous driver, since the farmer's decisions have little direct influence on price. The specific temporal, spatial, and organizational scale dependencies of endogenous and exogenous drivers and the specific linkages and interactions among drivers are assessed in the MA.

Whether a driver is exogenous or endogenous to a decision-maker is dependent upon the spatial and temporal scale. For example, a local decision-maker can directly influence the choice of technology, changes in land use, and external inputs (such as fertilizers or irrigation), but has little control over prices and markets, property rights, technology development, or the local climate. In contrast, a national or regional decision-maker has more control over many factors, such as macroeconomic policy, technology development, property rights, trade barriers, prices, and markets. But on the short time scale, that individual has little control over the climate or global population. On the longer time scale, drivers that are exogenous to a decision-maker in the short run, such as population, become endogenous since the decision-maker can influence them through, for instance, education, the advancement of women, and migration policies.

The indirect drivers of change are primarily:

- demographic (such as population size, age and gender structure, and spatial distribution);
- economic (such as national and per capita income, macroeconomic policies, international trade, and capital flows);
- sociopolitical (such as democratization, the roles of women, of civil society, and of the private sector, and international dispute mechanisms);
- scientific and technological (such as rates of investments in research and development and the rates of adoption of new technologies, including biotechnologies and information technologies); and
- cultural and religious (such as choices individuals make about what and how much to consume and what they value).

The interaction of several of these drivers, in turn, affects levels of resource consumption and differences in consumption both within and between countries. Clearly these drivers are changing—population and the world economy are growing, for instance, there are major advances in information technology and biotechnology, and the world is becoming more interconnected. Changes in these drivers are projected to increase the demand for and consumption of food, fiber, clean water, and energy, which will in turn affect the direct drivers. The direct drivers are primarily physical, chemical, and biological—such as land cover change, climate change, air and water pollution, irrigation, use of fertilizers, harvesting, and the introduction of alien invasive species. Change is apparent here too: the climate is changing, species ranges are shifting, alien species are spreading, and land degradation continues.

An important point is that any decision can have consequences external to the decision framework. These consequences are called externalities because they are not part of the decision-making calculus. Externalities can have positive or negative effects. For example, a decision to subsidize fertilizers to increase crop production might result in substantial degradation of water quality from the added nutrients and degradation of downstream fisheries. But it is also possible to have positive externalities. A beekeeper might be motivated by the profits to be made from selling honey, for instance, but neighboring orchards could produce more apples because of enhanced pollination arising from the presence of the bees.

Multiple interacting drivers cause changes in ecosystem services. There are functional interdependencies between and among the indirect and direct drivers of change, and, in turn, changes in ecological services lead to feedbacks on the drivers of changes in ecological services. Synergetic driver combinations are common. The many processes of globalization lead to new forms of interactions between drivers of changes in ecosystem services.

1.3.4 Cross-scale Interactions and Assessment

An effective assessment of ecosystems and human well-being cannot be conducted at a single temporal or spatial

scale. Thus the MA conceptual framework includes both of these dimensions. Ecosystem changes that may have little impact on human well-being over days or weeks (soil erosion, for instance) may have pronounced impacts over years or decades (declining agricultural productivity). Similarly, changes at a local scale may have little impact on some services at that scale (as in the local impact of forest loss on water availability) but major impacts at large scales (forest loss in a river basin changing the timing and magnitude of downstream flooding).

Ecosystem processes and services are typically most strongly expressed, are most easily observed, or have their dominant controls or consequences at particular spatial and temporal scales. They often exhibit a characteristic scale—the typical extent or duration over which processes have their impact. Spatial and temporal scales are often closely related. For instance, food production is a localized service of an ecosystem and changes on a weekly basis, water regulation is regional and changes on a monthly or seasonal basis, and climate regulation may take place at a global scale over decades.

Assessments need to be conducted at spatial and temporal scales appropriate to the process or phenomenon being examined. Those done over large areas generally use data at coarse resolutions, which may not detect fine-resolution processes. Even if data are collected at a fine level of detail, the process of averaging in order to present findings at the larger scale causes local patterns or anomalies to disappear. This is particularly problematic for processes exhibiting thresholds and nonlinearities. For example, even though a number of fish stocks exploited in a particular area might have collapsed due to overfishing, average catches across all stocks (including healthier stocks) would not reveal the extent of the problem. Assessors, if they are aware of such thresholds and have access to high-resolution data, can incorporate such information even in a large-scale assessment. Yet an assessment done at smaller spatial scales can help identify important dynamics of the system that might otherwise be overlooked. Likewise, phenomena and processes that occur at much larger scales, although expressed locally, may go unnoticed in purely local-scale assessments. Increased carbon dioxide concentrations or decreased stratospheric ozone concentrations have local effects, for instance, but it would be difficult to trace the causality of the effects without an examination of the overall global process.

Time scale is also very important in conducting assessments. Humans tend not to think beyond one or two generations. If an assessment covers a shorter time period than the characteristic temporal scale, it may not adequately capture variability associated with long-term cycles, such as glaciation. Slow changes are often harder to measure, as is the case with the impact of climate change on the geographic distribution of species or populations. Moreover, both ecological and human systems have substantial inertia, and the impact of changes occurring today may not be seen for years or decades. For example, some fisheries' catches may increase for several years even after they have reached unsustainable levels because of the large number of juvenile fish produced before that level was reached.

Social, political, and economic processes also have characteristic scales, which may vary widely in duration and extent. Those of ecological and sociopolitical processes often do not match. Many environmental problems originate from this mismatch between the scale at which the ecological process occurs, the scale at which decisions are made, and the scale of institutions for decision-making. A purely local-scale assessment, for instance, may discover that the most effective societal response requires action that can occur only at a national scale (such as the removal of a subsidy or the establishment of a regulation). Moreover, it may lack the relevance and credibility necessary to stimulate and inform national or regional changes. On the other hand, a purely global assessment may lack both the relevance and the credibility necessary to lead to changes in ecosystem management at the local scale where action is needed. Outcomes at a given scale are often heavily influenced by interactions of ecological, socioeconomic, and political factors emanating from other scales. Thus focusing solely on a single scale is likely to miss interactions with other scales that are critically important in understanding ecosystem determinants and their implications for human well-being.

The choice of the spatial or temporal scale for an assessment is politically laden, since it may intentionally or unintentionally privilege certain groups. The selection of assessment scale with its associated level of detail implicitly favors particular systems of knowledge, types of information, and modes of expression over others. For example, non-codified information or knowledge systems of minority populations are often missed when assessments are undertaken at larger spatial scales or higher levels of aggregation. Reflecting on the political consequences of scale and boundary choices is an important prerequisite to exploring what multi- and cross-scale analysis in the MA might contribute to decision-making and public policy processes at various scales.

1.4 Values Associated with Ecosystems

Current decision-making processes often ignore or underestimate the value of ecosystem services. Decision-making concerning ecosystems and their services can be particularly challenging because different disciplines, philosophical views, and schools of thought assess the value of ecosystems differently. One paradigm of value, known as the utilitarian (anthropocentric) concept, is based on the principle of humans' preference satisfaction (welfare). In this case, ecosystems and the services they provide have value to human societies because people derive utility from their use, either directly or indirectly (use values). Within this utilitarian concept of value, people also give value to ecosystem services that they are not currently using (non-use values). Non-use values, usually known as existence values, involve the case where humans ascribe value to knowing that a resource exists even if they never use that resource directly. These often involve the deeply held historical, national, ethical, religious, and spiritual values people ascribe to ecosystems—the values that the MA recognizes as cultural services of ecosystems.

A different, non-utilitarian value paradigm holds that something can have intrinsic value—that is, it can be of value in and for itself—irrespective of its utility for someone else. From the perspective of many ethical, religious, and cultural points of view, ecosystems may have intrinsic value, independent of their contribution to human well-being.

The utilitarian and non-utilitarian value paradigms overlap and interact in many ways, but they use different metrics, with no common denominator, and cannot usually be aggregated, although both paradigms of value are used in decision-making processes.

Under the utilitarian approach, a wide range of methodologies has been developed to attempt to quantify the benefits of different ecosystem services. These methods are particularly well developed for provisioning services, but recent work has also improved the ability to value regulating and other services. The choice of valuation technique in any given instance is dictated by the characteristics of the case and by data availability. (See Box 1.4.)

Non-utilitarian value proceeds from a variety of ethical, cultural, religious, and philosophical bases. These differ in the specific entities that are deemed to have intrinsic value and in the interpretation of what having intrinsic value means. Intrinsic value may complement or counterbalance considerations of utilitarian value. For example, if the aggregate utility of the services provided by an ecosystem (as measured by its utilitarian value) outweighs the value of converting it to another use, its intrinsic value may then be complementary and provide an additional impetus for conserving the ecosystem. If, however, economic valuation indicates that the value of converting the ecosystem outweighs the aggregate value of its services, its ascribed intrinsic value may be deemed great enough to warrant a social decision to conserve it anyway. Such decisions are essentially political, not economic. In contemporary democracies these decisions are made by parliaments or legislatures or by regulatory agencies mandated to do so by law. The sanctions for violating laws recognizing an entity's intrinsic value may be regarded as a measure of the degree of intrinsic value ascribed to them. The decisions taken by businesses, local communities, and individuals also can involve considerations of both utilitarian and non-utilitarian values.

The mere act of quantifying the value of ecosystem services cannot by itself change the incentives affecting their use or misuse. Several changes in current practice may be required to take better account of these values. The MA assesses the use of information on ecosystem service values in decision-making. The goal is to improve decision-making processes and tools and to provide feedback regarding the kinds of information that can have the most influence.

BOX 1.4

Valuation of Ecosystem Services

Valuation can be used in many ways: to assess the total contribution that ecosystems make to human well-being, to understand the incentives that individual decision-makers face in managing ecosystems in different ways, and to evaluate the consequences of alternative courses of action. The MA uses valuation primarily in the latter sense: as a tool that enhances the ability of decision-makers to evaluate trade-offs between alternative ecosystem management regimes and courses of social actions that alter the use of ecosystems and the multiple services they provide. This usually requires assessing the change in the mix (the value) of services provided by an ecosystem resulting from a given change in its management.

Most of the work involved in estimating the change in the value of the flow of benefits provided by an ecosystem involves estimating the change in the physical flow of benefits (quantifying biophysical relations) and tracing through and quantifying a chain of causality between changes in ecosystem condition and human welfare. A common problem in valuation is that information is only available on some of the links in the chain and often in incompatible units. The MA can make a major contribution by making various disciplines better aware of what is needed to ensure that their work can be combined with that of others to allow a full assessment of the consequences of altering ecosystem state and function.

The ecosystem values in this sense are only one of the bases on which decisions on ecosystem management are and should be made. Many other factors, including notions of intrinsic value and other objectives that society might have (such as equity among different groups or generations), will also feed into the decision framework. Even when decisions are made on other bases, however, estimates of changes in utilitarian value provide invaluable information.

1.5 Assessment Tools

The information base exists in any country to undertake an assessment within the framework of the MA. That said, although new data sets (for example, from remote sensing) providing globally consistent information make a global assessment like the MA more rigorous, there are still many challenges that must be dealt with in using these data at global or local scales. Among these challenges are biases in the geographic and temporal coverage of the data and in the types of data collected. Data availability for industrial countries is greater than that for developing ones, and data for certain resources such as crop production are more readily available than data for fisheries, fuelwood, or biodiversity. The MA makes extensive use of both biophysical and socioeconomic indicators, which combine data into policy-relevant measures that provide the basis for assessment and decision-making.

Models can be used to illuminate interactions among systems and drivers, as well as to make up for data deficiencies—for instance, by providing estimates where observations are lacking. The MA makes use of environmental system models that can be used, for example, to measure the consequences of land cover change for river flow or the consequences of climate change for the distribution of species. It also uses human system models that can examine, for instance, the impact of changes in ecosystems on production, consumption, and investment decisions by households or that allow the economy-wide impacts of a change in production in a particular sector like agriculture to be evaluated. Finally, integrated models, combining both the environmental and human systems linkages, can increasingly be used at both global and sub-global scales.

The MA incorporates both formal scientific information and traditional or local knowledge. Traditional societies have nurtured and refined systems of knowledge of direct value to those societies but also of considerable value to assessments undertaken at regional and global scales. This information often is unknown to science and can be an expression of other relationships between society and nature in general and of sustainable ways of managing natural resources in particular. To be credible and useful to decision-makers, all sources of information, whether scientific, traditional, or practitioner knowledge, must be critically assessed and validated as part of the assessment process through procedures relevant to the form of knowledge.

Since policies for dealing with the deterioration of ecosystem services are concerned with the future consequences of current actions, the development of scenarios of medium- to long-term changes in ecosystems, services, and drivers can be particularly helpful for decision-makers. Scenarios are typically developed through the joint involvement of decision-makers and scientific experts, and they represent a promising mechanism for linking scientific information to decision-making processes. They do not attempt to predict the future but instead are designed to indicate what science can and cannot say about the future consequences of alternative plausible choices that might be taken in the coming years.

The MA uses scenarios to summarize and communicate the diverse trajectories that the world's ecosystems may take in future decades. Scenarios are plausible alternative futures, each an example of what might happen under particular assumptions. They can be used as a systematic method for thinking creatively about complex, uncertain futures. In this way, they help us understand the upcoming choices that need to be made and highlight developments in the present. The MA developed scenarios that connect possible changes in drivers (which may be unpredictable or uncontrollable) with human demands for ecosystem services. The scenarios link these demands, in turn, to the futures of the services themselves and the aspects of human welfare that depend on them. The scenario building exercise breaks new ground in several areas:

- development of scenarios for global futures linked explicitly to ecosystem services and the human consequences of ecosystem change,
- consideration of trade-offs among individual ecosystem services within the ''bundle'' of benefits that any particular ecosystem potentially provides to society,
- assessment of modeling capabilities for linking socioeconomic drivers and ecosystem services, and
- consideration of ambiguous futures as well as quantifiable uncertainties.

The credibility of assessments is closely linked to how they address what is not known in addition to what is known. The consistent treatment of uncertainty is therefore essential for the clarity and utility of assessment reports. As part of any assessment process, it is crucial to estimate the uncertainty of findings even if a detailed quantitative appraisal of uncertainty is unavailable.

1.6 Strategies and Interventions

The MA assesses the use and effectiveness of a wide range of options for responding to the need to sustainably use, conserve, and restore ecosystems and the services they provide. These options include incorporating the value of ecosystems in decisions, channeling diffuse ecosystem benefits to decision-makers with focused local interests, creating markets and property rights, educating and dispersing knowledge, and investing to improve ecosystems and the services they provide. As seen in Box 1.2 on the MA conceptual framework, different types of response options can affect the relationships of indirect to direct drivers, the influence of direct drivers on ecosystems, the human demand for ecosystem services, or the impact of changes in human well-being on indirect drivers. An effective strategy for managing ecosystems will involve a mix of interventions at all points in this conceptual framework.

Mechanisms for accomplishing these interventions include laws, regulations, and enforcement schemes; partnerships and collaborations; the sharing of information and knowledge; and public and private action. The choice of options to be considered will be greatly influenced by both the temporal and the physical scale influenced by decisions, the uncertainty of outcomes, cultural context, and the implications for equity and trade-offs. Institutions at different levels have different response options available to them, and special care is required to ensure policy coherence.

Decision-making processes are value-based and combine political and technical elements to varying degrees. Where technical input can play a role, a range of tools is available to help decision-makers choose among strategies and interventions, including cost-benefit analysis, game theory, and policy exercises. The selection of analytical tools should be determined by the context of the decision, key characteristics of the decision problem, and the criteria considered to be important by the decision-makers. Information from these analytical frameworks is always combined with the intuition, experience, and interests of the decision-maker in shaping the final decisions.

Risk assessment, including ecological risk assessment, is an established discipline and has a significant potential for informing the decision process. Finding thresholds and identifying the potential for irreversible change are important for the decision-making process. Similarly, environmental impact assessments designed to evaluate the impact of particular projects and strategic environmental assessments designed to evaluate the impact of policies both represent important mechanisms for incorporating the findings of an ecosystem assessment into decision-making processes.

Changes also may be required in decision-making processes themselves. Experience to date suggests that a number of mechanisms can improve the process of making decisions about ecosystem services. Broadly accepted norms for decision-making process include the following characteristics. Did the process:

- bring the best available information to bear?
- function transparently, use locally grounded knowledge, and involve all those with an interest in a decision?

- pay special attention to equity and to the most vulnerable populations?
- use decision analytical frameworks that take account of the strengths and limits of individual, group, and organizational information processing and action?
- consider whether an intervention or its outcome is irreversible and incorporate procedures to evaluate the outcomes of actions and learn from them?
- ensure that those making the decisions are accountable?
- strive for efficiency in choosing among interventions?
- take account of thresholds, irreversibility, and cumulative, cross-scale, and marginal effects and of local, regional, and global costs, risk, and benefits?

The policy or management changes made to address problems and opportunities related to ecosystems and their services, whether at local scales or national or international scales, need to be adaptive and flexible in order to benefit from past experience, to hedge against risk, and to consider uncertainty. The understanding of ecosystem dynamics will always be limited, socioeconomic systems will continue to change, and outside determinants can never be fully anticipated. Decision-makers should consider whether a course of action is reversible and should incorporate, whenever possible, procedures to evaluate the outcomes of actions and learn from them. Debate about exactly how to do this continues in discussions of adaptive management, social learning, safe minimum standards, and the precautionary principle. But the core message of all approaches is the same: acknowledge the limits of human understanding, give special consideration to irreversible changes, and evaluate the impacts of decisions as they unfold.

Chapter 2

Overview of the MA Sub-global Assessments

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Main Messages ***30***

2.1 Important MA Design Features **30**
2.1.1 An Integrated Assessment
2.1.2 A Multistakeholder Assessment
2.1.3 A Multiscale Assessment
2.1.4 Bridging Knowledge Systems

2.2 The Sub-global Assessments and the MA Design **31**
2.2.1 Assessments at Various Scales
2.2.2 Engagement with Users: Meeting User Needs
2.2.3 A Learning Experiment
2.2.4 A Process to Build Assessment Capacity

2.3 The Sub-global Assessment Process in the MA **32**
2.3.1 The Initial Approach
2.3.2 The Bottom-up Approach and Selection Criteria
2.3.3 Funding for the Sub-global Assessments
2.3.4 Seed Funding to Develop Assessments
2.3.5 Core Funding for Full Assessment Activities
2.3.6 Approved Assessments and Associated Assessments

2.4 Participating Sub-global Assessments **34**
2.4.1 Geographical Coverage
2.4.2 Ecosystem Coverage

REFERENCES **35**

APPENDIXES

2.1 Approved Assessments **35**

2.2 Associated Assessments **39**

BOXES

2.1 Sources of Information Used in Writing this Volume

FIGURES

2.1 The MA's Nested, Multiscale Design
2.2 Locations of MA Sub-global Assessments*

TABLES

2.1 Selection Criteria for Approved and Associated Assessments

*This appears in Appendix A at the end of this volume.

Main Messages

The MA sub-global assessments were a key design feature of the MA. Within the MA process, the sub-global assessments complemented the global assessment, and were essential to the multiscale approach of the MA. The sub-global assessments also featured other aspects of the MA's technical design, including engagement with a full range of stakeholders at various scales and the adoption of an integrated approach involving natural and social sciences and other knowledge systems. The capacity-building objectives of the MA were also pursued in part through the sub-global assessments.

This volume presents the lessons learned and initial results from the sub-global assessments done at the local, national, and regional scales, and efforts to compare across these scales. Although many sub-global assessments are still on-going, this volume analyzes the processes pursued by the various assessments and, where possible, the substantive findings on ecosystem services and human well-being across the sub-global assessments. (Box 2.1 describes the sources of information used in writing this volume.) At the same time, this volume recognizes the constraints and challenges faced by the sub-global assessments and reflects on the outcomes of the process seen in this light. A total of 18 approved assessments and 16 associated assessments are included, covering every continent and most ecosystem types around the world. The volume takes readers from the rivers of southern Africa to the islands of the Caribbean, and from local villages in India to cities such as Stockholm.

2.1 Important MA Design Features

The sub-global assessments were a key component of the MA's technical design. This section reviews the MA's main design features with reference to the sub-global assessments, to give readers a full appreciation of the context in which the sub-global assessments were developed and undertaken.

2.1.1 An Integrated Assessment

The MA differs from sector-specific assessments undertaken in the past, such as those on climate change (IPCC 2002), global biodiversity (Heywood and Watson 1995), and ozone (UNEP 2003). After several of these assessments, the scientific community saw a need for an assessment that addressed the linkages among environmental problems, and possible solutions to these problems. In November 1998, the report *Protecting our Planet, Securing our Future: Linkages Among Global Environmental Issues and Human Needs,* prepared by a panel of 40 leading scientists, called for ''a more integrative assessment process for selected scientific issues, a process that can highlight the linkages between questions relevant to climate, biodiversity, desertification, and forest issues'' (Watson et al. 1998). The MA was designed to include an analysis of the linkages between different natural and human-induced drivers and responses, and their impact on ecosystem goods and services and human well-being.

2.1.2 A Multistakeholder Assessment

The MA was also designed to meet the needs of a range of users, namely, decision-makers who use assessment information to improve the management of ecosystems for human well-being. Key users were represented on the MA Board, including ecosystem-related international conventions, U.N. agencies, governments, nongovernmental organizations, the private sector, and local communities. Each sub-global assessment also has its own diverse set of users.

To ensure the legitimacy of the process, the MA exploratory steering committee decided not to even proceed to establish the assessment unless and until there had been a formal request for such an assessment from governments.

BOX 2.1

Sources of Information Used in Writing this Volume

Given the diversity of the sub-global assessments, as well as the fact that many were not complete at the time this report was written, the authors of this volume had to draw on a variety of sources of information when synthesizing and analyzing the experiences of the sub-global assessments. These include:

- *Formal assessment reports* from completed assessments (for example, SAfMA). Formal reports underwent a review process defined by the MA guidelines.
- *"State of the assessment" reports* from those sub-global assessments that had not yet been completed when this report was written. These averaged 30 pages each and were meant to summarize important information on the process and preliminary findings of each assessment regardless of the level of completion. The initial drafts of these reports were structured according to standardized questions developed by the Sub-global Assessment Working Group, covering all the topics and chapters in this volume; many of these reports draw on published literature and data sets. State of the assessment reports were included in the second round of review for this volume and are published online at the MA website, www.MAweb.org.
- *"Knowledge markets"* held at meetings of the Sub-global Assessment Working Group. Author teams for each chapter in this volume faced the challenge of obtaining information from all of the sub-global assessments, while individual assessment teams faced demands from multiple chapter author teams. The interactive solution to achieving a fast and effecting exchange of information was to structure a knowledge market at working group meetings. These were held in a large room, where tables were set up for each chapter team, and sub-global assessments rotated round the tables every fifteen minutes according to a schedule drawn up by the secretariat. Author teams prepared for a short but intense period of interaction with each sub-global assessment during the knowledge markets. In this volume, information from knowledge markets is cited as "KM–Name of assessment."
- *Survey questionnaires.* A number of chapter author teams e-mailed questionnaires to specific sub-global assessments to elicit further information in written form. In this volume, information from survey questionnaires is cited as "Q–Name of assessment."
- *Personal communication* through means other than knowledge markets. Personal communication—for example, through the direct participation of individuals from the various sub-global assessments in chapter teams at working group meetings—provided important additional information.

After substantial efforts, governments, through the four international conventions (CBD, UNCCD, Ramsar Convention, and CMS), took decisions in their Conferences of Parties authorizing the MA as a source of assessment input. The MA was relatively less successful at attracting the attention of the private sector and local and indigenous communities. (See Chapters 5 and 11 for discussion of engagement with communities in the sub-global assessments.)

2.1.3 A Multiscale Assessment

One of the innovations of the MA was its design as an assessment at multiple scales. While ecosystem change and biodiversity loss are of global environmental concern, and while there are global dimensions to such problems and their solutions, the sub-global dimensions are often of much greater significance. For example, the adverse effects of a given ecosystem change, such as desertification in a particular area, are more immediately felt at sub-global scales.

In light of the multiscale nature of both the issues involved and the decisions being made, it was clear early in the MA exploratory phase that a strictly ''global'' assessment would be insufficient. Causes and impacts of, as well as responses to, ecosystem change vary at different scales. Assessments at sub-global scales are needed because ecosystems are highly differentiated in space and time and because sound management requires careful local planning and action. Local assessments alone are insufficient, however, because some processes are global and because local goods, services, matter, and energy are often transferred across regions (Ayensu et al. 2000).

Chapter 4 of this volume expands on the rationale behind conducting a multiscale assessment, and includes an analysis of the benefits and the challenges of this design. For example, improved assessment findings were expected to be a major benefit of the multiscale design of the MA. The actual experience of the sub-global assessments has now shown the political ramifications of this design, including the empowerment of local communities, to be a highly significant result (findings of the Bridging Scales and Epistemologies Conference, Alexandria 2004; conference papers can be accessed at http://www.millenniumassessment.org/en/about.meetings.bridging.proceedings.aspx)

2.1.4 Bridging Knowledge Systems

The MA design also explicitly recognized that, apart from ''Western'' scientific knowledge, there are other forms of knowledge and knowledge systems that would be of relevance in any integrated assessment of ecosystem change and human well-being. Bringing in traditional knowledge and local knowledge was a key feature of a number of the sub-global assessments, particularly those undertaken with communities. The sub-global assessments were also conscious of the need to bridge disciplines (at a basic level, for example, bridging natural science and social science) and perspectives (for example, providing a bridge between nonprofit/NGO worldviews and those of the business sector). Chapter 5 examines these issues in detail.

2.2 The Sub-global Assessments and the MA Design

Consistent with the concepts underlying the MA's technical design, the sub-global assessments were encouraged to include design features such as a nested, multiscale structure and engagement with users.

2.2.1 Assessments at Various Scales

The MA design called for a set of ''nested'' assessments at various spatial scales. For example, a set of local community assessments could be nested within a broader assessment of a river basin, which in turn could be nested within a national assessment. Each of these assessments were meant to be proper assessments in their own right; local assessments, for instance, should not be merely case studies within a regional assessment, but should involve a complete assessment of conditions, trends, scenarios, and responses at the local scale, as well as engage with users as part of the assessment. (See Figure 2.1.) Several sub-global assessments incorporated a nested design into their assessment, but many relied on either case studies or users at multiple levels to achieve a multiscale effect. (See Chapters 3 and 5 for a more detailed discussion of this.)

The MA sub-global assessments included a range of assessments at various scales, from villages in India to cities such as Stockholm, from river basins in southern Africa to the large region of western China. Each of these assessments considered the MA conceptual framework, adapting it as needed to reflect the most important services and drivers, and was undertaken by local or national institutions in those locations. This multiscale approach was important because it enabled the assessment of ecological and social processes at the scale at which these processes operate, and the involvement of the relevant decision-makers and stakehold-

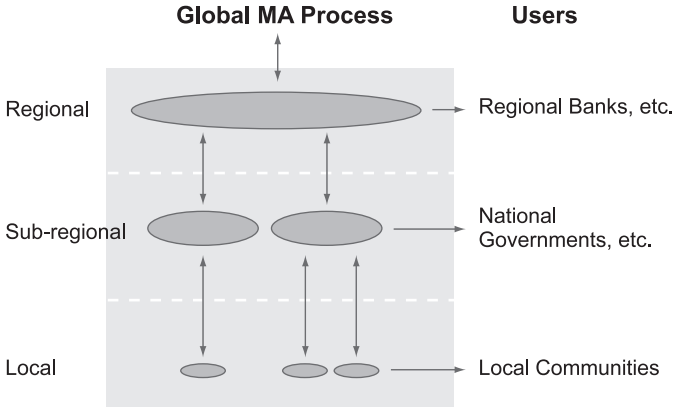

Figure 2.1. The MA's Nested, Multiscale Design. Nested sub-global assessments would consist of local assessments within the coverage of sub-regional assessments, which in turn would be in the area of a regional assessment. Any regional assessment (or, for that matter, any sub-global assessment) would be nested within the global assessment, by definition. At each scale, every sub-global assessment would directly meet the information needs of users at that scale.

ers at each scale. It also enabled analysis across sites, and the drawing of common lessons learned that might be applied in other places. Chapter 4 discusses the multiscale approach in detail, including the constraints faced by the sub-global assessments in attempting to put the full multiscale design into practice.

2.2.2 Engagement with Users: Meeting User Needs

Assessments at each scale were also meant to fully engage with stakeholders at that scale. That is to say, to be truly user-driven, an assessment at any given scale should primarily meet the needs of the users at that scale, who should be involved in defining the issues of concern for the assessment. So while the spatial ''scale'' of an assessment can often be defined in either natural or human terms (for example, the area assessed might be defined by the natural boundaries of a drainage basin or by the political boundaries of a country), it can also be thought of principally as being defined by the users of the assessment. For example, users within a well-established catchment management area would provide the principal reason to define and delineate the assessment at the scale of the catchment area.

2.2.3 A Learning Experiment

The design features described were developed at the initial MA design meetings, prior to the initiation of any sub-global assessment activities. Given some of the more innovative and experimental aspects of the MA design, it was clearly expected that the MA experience in general, and the sub-global assessments in particular, would be a learning process for all involved. Some individuals involved in the MA design meetings subsequently became directly involved in the work of a sub-global assessment. Sub-global assessments took the MA conceptual framework, along with the criteria for becoming a sub-global assessment, as the starting points for undertaking an assessment. Thus sub-global assessments became an experiment in applying the MA conceptual framework in widely varying environmental and socioeconomic contexts. In some cases, tensions quickly arose between the desire to follow the MA design guidelines and meeting a diverse set of specific user needs, which was also an MA priority.

2.2.4 A Process to Build Assessment Capacity

One of the main objectives of the MA was to build capacity to undertake integrated ecosystem assessments and to use information from such assessments. The sub-global assessments were a key element in the strategy to achieve this capacity-building objective—technical experts and users involved in each sub-global assessment would naturally develop improved capacity from the experience of undertaking the assessment. The sub-global assessments made use of the MA network of experts, experience-sharing opportunities, and much ''self-help'' to overcome technical hurdles. Most assessments also held regular workshops and feedback sessions with decision-makers and other stakeholders to build further capacity for understanding the links between ecosystem services and human well-being.

2.3 The Sub-global Assessment Process in the MA

Once the need to have a set of sub-global assessments was identified, the MA exploratory steering committee recommended that a separate working group be established for this purpose, in addition to the three working groups focused on the global assessment. This working group eventually included two members of the MA Panel who acted as co-chairs, a technical support unit from the MA Secretariat, key individuals from the various sub-global assessments, and a number of additional independent participants interested in the issues addressed by these assessments.

From the beginning, even within the MA, there were different understandings and expectations of what sub-global assessments were meant to achieve. This related in part to the differences and the varying needs of users and decision-makers at the different scales the global and sub-global components of the MA sought to address. The evolution of the MA design over a three-year period with different, though overlapping, groups of people involved also contributed to the differences in understandings and expectations.

Those oriented to global level issues saw sub-global assessments primarily as a vehicle for enriching global assessment findings and for getting feedback from finer scales. Sub-global assessments, for their part, understood their role as primarily addressing the issues and needs of users and audiences at their respective levels. To help ensure and facilitate the links and flow of information between the global and sub-global components of the MA, a team of three individuals was constituted as a core ''linkage'' team, who worked together with a wider network of individuals who were involved in both the global and sub-global assessments in various capacities.

2.3.1 The Initial Approach

After an open solicitation of proposals for assessments in 2000, an expert group recommended that the MA seek to establish clusters in Southern Africa, Southeast Asia, Europe, and Central America (MA 2001), based on expressions of interest that had been received. The MA Board approved this regional focus at its first meeting in July 2001, and planning workshops were held in each region in 2001 and early 2002. A special effort was made to identify key individuals and institutions from these regions, and to invite them to the initial design workshops, in attempts to catalyze nested clusters of assessments in these regions.

2.3.2 The Bottom-up Approach and Selection Criteria

By the time of the January 2002 meeting of the MA Board, only one of the initial focal regions—Southern Africa—was in the process of successfully launching a cluster of assessments. It became evident that it would be difficult to develop full nested assessments in all of the chosen focal regions. At the same time, the MA process generated a considerable amount of interest from a number of existing and

proposed initiatives around the world, and there were a growing number of requests to join the MA. One example was the set of on-going local assessments conducted in India by the Indian Institute of Science.

Sub-global participants in the MA design meetings and the co-chairs of the MA Sub-Global Assessment Working Group were by then arguing that a ''bottom-up'' process of establishing the assessments would be more effective, suggesting that MA funds would be best used as ''seed grants'' for a larger number of assessments. Those assessments could then seek their own larger grants from sources other than the MA, resulting, it was hoped, in a better leveraging of MA resources and more solid grounding of the assessments in regions demonstrating the greatest interest among donors and experts.

At the same time, it was viewed as important that all assessments involved in the MA should meet some minimum standards, and make a contribution to the overall MA process. The solution was to establish a formal approval process and a set of criteria that all sub-global assessments should meet. These criteria were:

- use of the MA conceptual framework,
- user engagement, and
- adherence to MA policies (see MA 2002).

The benefits of the bottom-up approach included a greater number of assessments with established user groups meeting existing needs; a wider audience for the MA in a greater number of regions; a more diverse pool of people (along with their experiences, methodologies, and worldviews) collaborating within the sub-global working group; and a higher likelihood of use of assessment results in follow-up action and decision-making. The costs of this approach included few assessments with sufficient funding to complete their work (see sections on funding below); interrupted assessment processes and longer timeframes as funding was secured in a piecemeal fashion; less MA control over sub-global assessment design and use of the MA conceptual framework; and a lack of assessments in some key regions and ecosystems.

2.3.3 Funding for the Sub-global Assessments

The MA project document allocated $7.9 million (37% of the overall project budget) to the sub-global assessments and related support. Of this amount, $3.5 million was in the form of commitments for co-financing or in-kind support to specific sub-global assessments. For example, $1.5 million was provided by the government of China for the western China sub-global assessment; $400,000 was in the form of a grant provided by the government of Norway for the Southern Africa sub-global assessment, to match the $500,000 provided by the MA to SAfMA. Thus, excluding co-financing and in-kind support earmarked for specific assessments during the initial project design, $4.4 million was available to support other sub-global assessments, working group meetings and exchange activities, publications costs, and panel and secretariat coordination functions. At the same time, not all of the $3.5 million committed to specific assessments was ultimately made available to those assessments. The actual amounts of funding given in grants to the sub-global assessments are described in the sections below.

2.3.4 Seed Funding to Develop Assessments

A challenge faced by many of the proposed assessments was to secure funding for their assessment work via traditional mechanisms such as international and national funding programs and donors. The ''seed grants'' provided by the Sub-global Working Group to many assessment initiatives in their early stages were intended to enable assessment teams to hold design meetings with relevant stakeholders and put together proposals seeking funding for their full slate of assessment activities.

The key criteria used for the approval of seed funding included:

- institutional capacity,
- co-financing, and
- contribution to the MA process and users.

A total of 13 candidate assessments received an average of $16,000 in seed funding during the first two years of the MA. Of these, 8 assessments obtained formal approval from the MA Board as full components of the MA. A number of assessments also obtained formal approval without having received seed funding (see the section below on the category of approved assessments).

2.3.5 Core Funding for Full Assessment Activities

Apart from SAfMA, which received $900,000 (as noted earlier), ten sub-global assessments received grants averaging $70,000 each. Thus almost all sub-global assessments have needed to raise additional funds from sources other than the MA.

While all sub-global assessments benefited from significant in-kind contributions from collaborating agencies and participating governments—notably the time of technical staff, facilities, support for meetings, etc.—securing donor support for full funding of planned assessment activities has proven to be a challenge for many of the sub-global assessments. This has raised the question of whether it would have been more effective to use MA funds to support fewer but completely nested multiscale assessments such as in Southern Africa. At the time the MA funding became available, however, the other initial focal regions identified were not ready to launch fully nested assessments, while the funds available would have supported only one other set of assessments like SAfMA.

2.3.6 Approved Assessments and Associated Assessments

The MA was designed as a process with a limited duration, expected to conclude in 2005. This had implications for the sub-global assessments and their contributions to the overall synthesis of findings and lessons learned. The sub-global assessments were requested to provide a ''state of the assessment'' or final report by December 2003, depending on the extent to which each was completed. Many assessments that had been classified as ''candidate assessments,'' with the expectation that they would graduate to become ''approved

assessments,'' had still not progressed by this late date. In addition, new assessments were still interested in joining the MA with no expectation of contributing substantially to this volume, and many of these did not meet all the criteria that had been established for formal approval. (In addition to access to the technical resources and networks, the perceived increase in credibility, or even political advantage, from association with the MA was often one of the motivations for joining the MA process.)

The decision was thus taken to establish a separate category of ''associated'' assessments, based on a set of modified criteria. (See Table 2.1.) All candidate assessments were absorbed into this new category. Association provided the platform for these assessments to continue to be involved with the MA, through attendance at working group meetings, access to networks and technical resources, some limited funding for specific purposes, etc.

2.4 Participating Sub-global Assessments

The sub-global assessment process involved a large number of assessments covering all continents around the globe. A total of 18 assessments were approved by the MA Board, and as of March 2005 all but one (Norway) are complete or currently under way. An additional 16 assessments became associated assessments. Many associated assessments have made significant contributions to the process and to conclusions presented in this volume, and can be expected to make substantial additional contributions to our understanding after the MA process is complete. The complete list of approved assessments is presented in Appendix 2.1, while the list of associated assessments is in Appendix 2.2, at the end of this chapter. Brief descriptions of individual sub-global assessments can be found in Appendix B at the end of this volume.

2.4.1 Geographical Coverage

The assessments taking part in the MA process have broad geographical coverage, and are found in all the main continents. Chapter 6 provides insights on how the various sub-global assessments were initiated. The set of sub-global assessments at the first Sub-global Working Group meeting was notable in that there were several regional gaps in global coverage by the assessments. There were no assessments in either North or Central America, only two in South America, and none in East or West Africa. Because the process relied on a ''bottom-up'' generation of assessment proposals, and because the donor funds available to support the establishment of assessments could only be used in developing countries, there was only partial control over the final distribution of assessments. However, the MA proactively sought to fill some of the gaps and recruited local organizations, such as RIDES in Chile, to initiate assessments in their region. It should be noted that there was never a goal for the group of sub-global assessments to be representative of the world's regions or ecosystems. Assessments are under way in most geographic regions, although the number of assessments in developing countries outnumbers those in developed countries. (See the introductory section ''MA Objectives, Focus, and Approach'' for a map showing the location of the MA sub-global assessments worldwide.)

2.4.2 Ecosystem Coverage

The ecosystem types covered by the sub-global assessments—based on the MA system definitions (MA 2003)—include all systems except polar and deep water marine ecosystems. The MA sub-global assessments were not intended to represent a scientific sample of global ecosystems. For many ecosystem processes, more accurate and consis-

Table 2.1. Selection Criteria for Approved and Associated Assessments

MA Selection Criteria	Approved Assessments	Associated Assessments
Assess ecosystem services and the consequences of ecosystem change for human well-being	essential	examine the linkages between ecosystems and human well-being
Include assessment components of conditions/ trends, scenarios, and responses	essential	not necessarily all components
Multiscale interactions	nested design an important priority	preferable, but not strictly necessary
Multisectoral and interdisciplinary approach	essential	essential
User involvement	essential	essential
Timing	contribute to MA by end-2003	no time bar
Peer review	follow MA guidelines	preferable
Transparency	follow MA guidelines	make information on governance and financing publicly available
Data management and access	follow MA guidelines	provide information on data sources used
Intellectual property rights	follow MA guidelines	follow international practice
Evaluation	participate in MA evaluation	not required
Accession procedure	approval by MA Board	approval by MA director in consultation with Sub-global Working Group co-chairs

tent information is available from remote sensing data or existing global monitoring processes, than could be obtained through even a far larger sample of sub-global assessments than the MA could conceive of supporting. Nor were the sub-global assessments intended to focus only on areas facing the most significant problems related to ecosystems. One assumption implicit in the MA was that better information on ecosystem services, and the consequences of changes in those services, could enhance decision-making concerning the management of ecosystems, whether or not the systems were already facing serious problems of resource degradation. Figure 2.2 in Appendix A compares the WWF ecoregions with the areas of coverage of selected sub-global assessments. (See Objectives, Focus, and Approach for a summary of the ecosystem coverage of the MA sub-global assessments worldwide.)

The ecoregions sampled by the various sub-global assessments can be expected to have had a significant influence on the types of ecosystem services examined. User needs and the issues specific to each location were highly important in determining the services assessed. However, the very nature of the MA, with its focus on human well-being, does place a significant emphasis on basic ecosystem services that are important for human survival such as water supply and food production. This interplay between a diversity of ecosystems and the common requirements for human survival is reflected in the ecosystem services selected in various sub-global asssessments. (See Appendixes 2.1 and 2.2 for the main ecosystem services assessed, and for short-hand references used throughout this volume.)

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Appendix 2.1. Approved Assessments (short names for assessments in parentheses)

Approved Assessment	Location	Coordinating Institution	Users	Ecosystem Types	Ecosystem Services	Scales	Time Frame
Altai-Sayan Ecoregion (Altai-Sayan)	Transboundary ecoregion in Altai and Sayan mountain ranges in Russia, Mongolia, Kazakhstan, and China	WWF Russia Programme Office, Moscow, Russia	national and regional governments local communities	dryland forest inland water mountain	food and grazing timber and forest products biodiversity wind power tourism	ecoregion national basin local	2003–05
San Pedro de Atacama, Chile (San Pedro de Atacama)	Salar de Atacama salt marsh in the northern desert of Chile	RIDES, Santiago, Chile	indigenous people government agencies tour operators mining companies	inland water dryland	food water biodiversity runoff regulation cultural others	local	2003–05
Caribbean Sea	Regional assessment of marine and island systems in the Caribbean	University of the West Indies, St. Augustine, Trinidad	governments intergovernmental processes	coastal island marine	food water biodiversity cultural	regional	2003–05
Coastal British Columbia, Canada (Coastal BC)	Northern and central coastal region of British Columbia	Coast Information Team, Victoria, BC, Canada	logging companies indigenous groups government agencies	coastal inland water forest mountain	food biodiversity fiber and timber runoff regulation cultural	regional sub-national	2002–04

Appendix 2.1. ***continued***

Approved Assessment	Location	Coordinating Institution	Users	Ecosystem Types	Ecosystem Services	Scales	Time Frame
Bajo Chirripó, Costa Rica (Bajo Chirripó)	Chirripó River Basin–Caribbean slope	Asociacion Ixacavaa, San Jose, Costa Rica	local communities	cultivated forest inland water	food water biodiversity fiber and timber cultural others	local	2003–05
Forest and agro-ecosystem trade-offs in the humid tropics (Tropical Forest Margins)	Cross-cutting assessment of sites in the forest margins of the humid tropics in South America, Africa, and Southeast Asia	Alternatives to Slash-and-Burn Programme, hosted by the World Agro-forestry Centre, Nairobi, Kenya	farmers and communities policy-makers	forest cultivated	food water biodiversity carbon sequestration fiber and timber runoff regulation others	local benchmark sites ecoregion national	2003–05
India local villages (India Local)	Local villages in Karnataka and Maharashtra states in India	Center for Ecological Sciences, Bangalore, India	village councils government agencies NGOs	cultivated forest inland water	food water fuel and energy biodiversity fiber and timber runoff regulation cultural others	local	2000–04
Glömma Basin, Norway (Norway)	Pilot assessment in the Glömma Basin in southern Norway	Norwegian Institute for Nature Research	government agencies private sector	cultivated forest inland water mountain	recreational accessibility of landscape agricultural production hunt yields–moose and reindeer timber hydroelectric power	basin	2001–04
Papua New Guinea (PNG)	Coastal, small island, and coral reef systems nationwide, with a focus on Milne Bay Province	Australian National University and University of Papua New Guinea	local communities government agencies NGOs UNDP	coastal cultivated island marine	food water fuel and energy biodiversity fiber and timber runoff regulation cultural others	national provincial local community	2002–07

Appendix 2.1. ***continued***

Approved Assessment	Location	Coordinating Institution	Users	Ecosystem Types	Ecosystem Services	Scales	Time Frame
Vilcanota, Peru (Vilcanota)	Vilcanota region	ANDES, Cusco, Peru	local communities NGOs government agencies research organizations	cultivated dryland mountain	food water runoff regulation biodiversity tourism cultural others	sub-regional local	2003–05
Laguna Lake Basin, Philippines (Laguna Lake Basin)	Laguna Lake Basin near Metro Manila	University of the Philippines, Los Banos	regulatory and government agencies scientific community NGOs	forest inland water cultivated	food water biodiversity carbon sequestration cultural others	basin local	2002–05
Portugal	National assessment with case studies at the basin level (Mondego Basin and Mira Basin) and the local level (Sistelo, Quinta da França, Herdade de Ribeira Abaixo, and Castro Verde)	Center for Environmental Biology, Faculty of Sciences of the University of Lisbon, Portugal	government agencies private sector NGOs scientific community local communities	coastal cultivated dryland forest inland water island marine mountain urban	food water biodiversity carbon sequestration fiber and timber runoff regulation cultural others	national basin local	2003–05
São Paulo Green Belt, Brazil (São Paulo)	São Paulo City Green Belt Biosphere Reserve	Instituto Florestal, São Paulo, Brazil	government agencies and public offices local communities private sector scientific community NGOs media international organizations	coastal cultivated forest inland water urban	biodiversity freshwater Food security Timber and other forest resources climate regulation runoff regulation carbon sequestration sustainable tourism and other cultural benefits	local river basin	2003 (preliminary assessment) 2005–07 (full assessment)

Appendix 2.1. ***continued***

Approved Assessment	Location	Coordinating Institution	Users	Ecosystem Types	Ecosystem Services	Scales	Time Frame
Southern Africa Millennium Assessment (SAfMA)	Regional assessment of southern Africa (SAfMA Regional) Gariep Basin (SAfMA Gariep) Zambezi Basin (SAfMA Zambezi) Local assessments in Gariep Basin (SAfMA Livelihoods) Gorongosa-Marromeu (SAfMA G-M)	University of Zimbabwe, Harare	government agencies scientific community NGOs local communities	coastal cultivated dryland forest inland water marine urban	food water fuel and energy biodiversity fiber and timber cultural others	regional basin local	2001–04
Sweden: Stockholm Urban and Kristianstad Wetlands (Sweden SU and Sweden KW)	Local assessments: Stockholm Urban Assessment and Kristianstad Wetlands	Stockholm University, Sweden	local communities government agencies	cultivated inland water urban	food water biodiversity carbon sequestration fiber and timber runoff regulation cultural others	local	2001–05
Northern Range of Trinidad (Northern Range)	Northern Range	The Cropper Foundation, Port of Spain, Trinidad	government agencies local communities technical cooperation agencies research organizations private sector NGOs/CBOs	coastal forest inland water mountain	water timber and non-wood forest products biodiversity cultural food runoff regulation land space for housing and agriculture minerals	sub-national local (selected communities)	2003–05
Downstream Mekong Wetlands, Viet Nam (Downstream Mekong)	Downstream Mekong wetlands	Institute of Geography, Hanoi, Viet Nam	local communities government agencies and decision-makers NGOs	coastal cultivated inland water	food water fuel and energy biodiversity carbon sequestration fiber and timber runoff regulation cultural others	local	2002–04
Western China	Entire western region of China, with six typical sites	Institute of Geographical Sciences and Natural Resources Research, Beijing, China	government agencies at national and local levels	cultivated dryland forest inland water mountain	food water biodiversity carbon sequestration runoff regulation others	regional local	2002–04

Appendix 2.2. Associated Assessments (short names for assessments in parentheses)

Associated Assessment	Location	Coordinating Institution	Users	Ecosystem Types	Ecosystem Services	Scales	Time Frame
Alaskan Boreal Forest (Alaska)	Yukon River Basin (Interior Alaska and southern Yukon Territories)	University of Alaska Fairbanks	local communities fire managers (Bureau of Land Management Alaska Fire Service and Alaska Division of Forestry)	Forest Inland water	climate regulation food and fiber cultural heritage maintenance of disturbance regime nutrient cycling and primary production	transnational (portions of U.S. and Canada) regional (Yukon River Basin) local (selected communities and adjacent forests)	2003–07
Arafura and Timor Seas	Indonesia, Timor-Leste, and Australia	Arafura and Timor Seas Experts Forum	governments indigenous communities	coastal island marine	fish/food security biodiversity carbon sequestration coastal livelihoods	regional national local	2003–04
Argentine Pampas, Argentina (Argentine Pampas)	Argentine Pampas	National Institute of Agricultural Technology and CONICET, Argentina	national and regional government local community	cultivated	food water purification soil formation nutrient cycling habitat provision cultural and aesthetic	transnational basin regional local	2003–2005/06
Central Asia Mountains	Pamir and Tianshan mountain ranges	Central Asia Regional Environment Centre, Almaty, Kazakhstan	national and local governments local communities regional and international organizations NGOs and other civil society organizations mass media	mountain	food water biodiversity soil others	regional basin local	2003–06
Coffee-growing regions of Colombia (Colombia)	Coffee-growing regions in the Colombian Andes	Alexander von Humboldt Institute and CENICAFE, Colombia	government agencies National Federation of Coffee-growers regional environmental authorities	cultivated mountain	food water biodiversity cultural	sub-national local	2003–07
Eastern Himalayas	Northeast India	Ashoka Trust for Research in Ecology and the Environment, India	local government local community	forest mountain	food water fuel and energy biodiversity cultural	sub-national local	2002–05

Appendix 2.2. ***continued***

Associated Assessment	Location	Coordinating Institution	Users	Ecosystem Types	Ecosystem Services	Scales	Time Frame
Sinai, Egypt (Sinai)	Sinai Peninsula, Egypt	Suez Canal University, Ismailia, Egypt; with UNEP Regional Office for West Asia	Bedouins government agencies developers research institutions	dryland mountain	minerals, marble, gravel biodiversity medicinal plants runoff regulation cultural others	local	2003–07
Fiji	Suva Coral Coast Gau	University of the South Pacific, Suva, Fiji	local government and development agencies	coastal island	food water fuelwood building materials others	local	2004–06
Hindu Kush–Himalayas (HKH Mountains)	Afganistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal , Pakistan	International Centre for Integrated Mountain Development, Nepal	national and local governments national and international agencies	inland water mountain	water and hydrology biodiversity land and soil cultural and spiritual	regional basin local	2003–06
Indonesia	Jakarta Bay (Pulau Seribu) Bunaken National Park, Sulawesi	Ministry of Environment	local government and NGOs	coastal island marine	fish/food security biodiversity coastal livelihoods	local	2003–04
Indian Urban Resource (India Urban)	Western Ghats, with focus on Pune-Bombay belt and Madurai	RANWA, Pune, India	local government- NGOs local community research institutions	urban	food water fuel and energy biodiversity carbon sequestration cultural others	sub-national local	2002–04
Tafilalt Oasis, Morocco (Tafilalt Oasis)	Tafilalt Oasis, Morocco	National Environmental Observatory, State Secretary of the Environment, Morocco	local communities NGOs national government research institutions	cultivated dryland	agricultural products fresh water nutrient cycling climate and disease regulation cultural	sub-national local	2004–07

Appendix 2.2. ***continued***

Associated Assessment	Location	Coordinating Institution	Users	Ecosystem Types	Ecosystem Services	Scales	Time Frame
Northern Australia Floodplains	Along the Alligator River, whose catchments encompass much of Kakadu National Park, around 200 km east of Darwin	Environmental Research Institute of the Supervising Scientist (Federal Department of Environment and Heritage), in collaboration with local landholders	park managers local community scientists	inland water	food water biodiversity runoff regulation cultural others	regional catchment sub-catchment	2003–05
Assir National Park, Saudi Arabia (Assir National Park)	Assir National Park in Assir Province	Government of Saudi Arabia, Presidency of Meteorology and Environment; with UNEP Regional Office for West Asia	local community government agencies scientific community tourism businesses	cultivated forest mountain	agricultural production grazing flood control cultural	sub-regional local	2003–06
Trade, Poverty, and the Environment	Chile, China, India, Madagascar, Mexico, South Africa, and Viet Nam	WWF's Macroeconomics Programme Office	business civil society governments international bodies	coastal cultivated drylands forest inland water marine mountain	agricultural production cultural fresh water	international regional national local	2002–2005
Northern Highlands Lake District, Wisconsin, United States (Wisconsin)	Northern Highlands Lake District	University of Wisconsin-Madison	local community government agencies scientific community	forest inland water	fresh water fiber and timber regulation of water, air quality, and climate spiritual and religious values, aesthetics, recreation and tourism	regional (many large watersheds) larger watersheds (many lakes) watersheds of individual lakes	2000 on (no end date at time of writing)

Chapter 3

Linking Ecosystem Services and Human Well-being

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Main Messages ***45***

3.1 Introduction **45**

3.2 What Are "Ecosystem Services"? **45**

3.3 Human Well-being and Its Components **47**

3.4 Links between Ecosystem Services and Human Well-being **51**
3.4.1 Provisioning Services
3.4.2 Regulating Services
3.4.3 Cultural, Spiritual, and Recreational Services
3.4.4 Supporting Services

3.5 Trade-offs and Congruence between Services **55**

3.6 Trade-offs between Ecosystem Services and Human Well-being **55**

3.7 Issues of Equity and Access **57**

3.8 The Consequences of Ignoring the Link between Well-being and Ecosystem Condition **57**

3.9 Final Remarks **58**

REFERENCES **59**

BOXES

3.1 Ecosystem Services and the Failure of Civilizations

3.2 Human Well-being as Perceived by Selected Communities Assessed

FIGURES

3.1 Examples of Some of the Possible Shapes of the Relationship between Human Well-being and Ecosystem Service Supply

TABLES

3.1 Ecosystem Services in Selected MA Sub-global Assessments

3.2 Components of Human Well-being

3.3 Components of Human Well-being in Selected MA Sub-global Assessments

Main Messages

Ecosystem services are indispensable to the well-being of all people in all places. Ecosystem services are the benefits that people obtain from ecosystems, including food, natural fibers, a steady supply of clean water, regulation of pests and diseases, medicinal substances, recreation, and protection from natural hazards such as floods. Human well-being consists of security, the basic materials for a viable livelihood (food, shelter, clothing, energy, etc., or the income necessary to purchase them), freedom and choice, good health, and good social-cultural relations. Links exist in both directions between the flow of ecosystem services and the level of human well-being. These linkages can be illustrated at all scales, from local to global; in all places in the world, from the least to the most developed; and for all peoples, from the poorest to the wealthiest and the rural to the urban and industrialized. There are important issues of equity involved: Who experiences the gains and losses in ecosystem services under conditions of ecosystem change? How are the services and well-being distributed across space and/or time? These issues can only be satisfactorily resolved by adopting a comprehensive approach to development that simultaneously considers ecological, social, and economic outcomes, balancing the interests of all affected groups, as well as the benefits in the present against the options that will be available to future generations.

Despite their obvious importance, ecosystem services are in decline in many places around the world (though some services are increasing in some areas, for example food production in managed ecosystems). In some cases, the loss may be too gradual to be noticed, or may be compensated by increases in other services or in some aspects of human well-being. In other cases, the loss of services is borne by people other than those causing the decline. A special case of the latter occurs when future generations bear the loss, while current generations reap the benefits.

Where the link between ecosystem services and human well-being is clear and immediate, affected people are more likely to develop regulatory institutions to ensure the continued supply of services. In some situations, though, the flow of services may be appropriated by more powerful groups. Also, if the link is obscured, ecosystem services may be undervalued and a severe loss of service can then result. Common reasons for the link not being apparent to all parties include: slow feedbacks (effects are felt long after the causes have taken place); displacement in space (effects are felt far from the cause); or displacement in social class (effects are principally felt by people without power).

The relationship between ecosystem services and human well-being can take on several different forms. Often, rising incomes are initially accompanied by declines in some ecosystem services. Once a sufficient level of wealth is achieved, societal priorities may emphasize the quality of the environment and the services it delivers. In other cases, there is no evidence for such a turn-around, and some services may decline continuously with increasing wealth. In yet other cases, a particular service may improve continuously in tandem with increasing wealth. Note that we do not equate human well-being with wealth; wealth is simply one important and frequently measured component of well-being.

In places where there are no other social safety nets, diminished human well-being tends to increase the immediate dependence on ecosystem services. The resultant additional pressure can damage the capacity of those local ecosystems to deliver services, and this capacity can decline to such a degree that the probability of disaster or conflict increases. The non-linear nature of both human and ecological systems and of the relationship between them means that there are some ecosystem damage thresholds that, if crossed, may prove to be irreversible. In this important respect, the future of the society-ecosystem relationship is rarely a simple linear extrapolation of recent trends or current conditions.

3.1 Introduction

This chapter interprets the MA conceptual framework (summarized in Chapter 1) in the context of local and regional assessments, with specific reference to ecosystem services and human well-being. The chapter illustrates, with examples from the sub-global assessments, different approaches to the measurement of human well-being; linkages between ecosystem services and well-being; and the challenges inherent in identifying and attributing those links. The chapter is not meant to be comprehensive in its treatment of these areas: the main findings of the sub-global assessments follow in the eight topic chapters and the final synthesis chapter of this volume. In addition, reports from each sub-global assessment have been, or will be, independently published.

History shows that human well-being, and indeed the persistence of civilizations, is strongly linked to the capacity of their environments to continue to deliver ecosystem services at the local to regional scale. (See Box 3.1.) The linkage works in both directions:

- human well-being depends, to a large measure, on the many services provided by nature; and
- the state of the environment is affected by the size and consumption patterns of human populations in ways that reduce or increase (at least temporarily) the supply of ecosystem services.

If the connection between ecosystem services and human well-being is so strong, why do people behave in an apparently irrational manner by undermining factors necessary for their own good? There are several possible reasons. Many ecosystem services, such as a benign climate, soil fertility, or the flow of water in rivers, are easily taken for granted, especially by urban people in industrial economies. Many people tend to think of the supply of these services as happening automatically and eternally, or they are unaware of their importance to them. In other cases, for instance, with respect to the maintenance of biodiversity, the causal connection with human well-being is not immediately and universally obvious. Who is disadvantaged if some obscure insect becomes extinct? In yet other cases, the loss of a service is a cost borne collectively, while the benefits arising from an action that lead to that loss are enjoyed by a smaller group, resulting in behavior that is rational for the individual but irrational for society as whole. In many instances, the feedback loop between declining ecosystem services and human well-being is slow, or operates at a distance, and this results in the warning signals being missed. Insensitivity to the impending collapse of ecosystem services appears to be a common and widespread phenomenon in historical examples.

3.2 What Are "Ecosystem Services"?

Ecosystem services are the benefits that people obtain from ecosystems (MA 2003). It is clear that the forest dwellers of Papua New Guinea, for example, gain a direct and immediate benefit from the subset of foods that they harvest from their rainforest ecosystem. Less obvious, but nonetheless as

BOX 3.1

Ecosystem Services and the Failure of Civilizations

There is thought-provoking, though sometimes controversial, evidence that failure to maintain an adequate supply of ecosystem services has been a major cause of societal collapse and attendant loss of human well-being in the past.

The best-established example is Easter Island in the southeast Pacific (Tainter 1988; Diamond 1997; Diamond 2005). Polynesian people settled the previously uninhabited island around 900 AD. They thrived initially, but eventually denuded the island of forest. The trees were needed as rollers for transporting massive stone statues, the poker-faced *moai,* to their ocean lookout posts. Massive soil erosion ensued, impairing the growth of crops. Wooden canoes for fishing could no longer be built. The seeds of native plants were eaten by introduced rats, and pollinating birds were lost. In consequence, from an estimated peak population of around 7,000 in the fifteenth century, numbers dwindled, conditions deteriorated, and warfare and cannibalism broke out. When Dutch explorers landed in 1722, there were fewer than 2,000 inhabitants—plus several hundred *moai.* By the nineteenth century, the survivors had dwindled to several hundred.

The civilizations in Mesopotamia, in the Tigris-Euphrates valley, were among the first examples of agrarian states. In earlier millennia within the surrounding Eastern Mediterranean region, between 7,000 and 11,000 years ago, several important crops and animals were probably domesticated. Writing, on clay tablets, appears to have been invented in Sumeria, the first major Mesopotamian civilization, around 5,000 years ago. Archaeological and historical evidence indicates that Sumeria suffered progressively from salinization of agricultural lands, following extensive deforestation and the use of irrigation (Jacobsen and Adams 1958; Ponting 1992). Between 4,000 and 5,000 years ago, wheat was gradually replaced by barley, a more salt-tolerant cereal. During the subsequent half millennium, Sumeria's agricultural productivity declined below the population's needs, causing the center of Mesopotamian civilization to move northwards, to Babylon.

The Mayan civilization is thought to have collapsed around a thousand years ago under the dual stress of an adverse regional climatic cycle extending over several centuries and excessive agricultural demand on fresh water supplies (Diamond 1997; Fagan 1999).

On the other hand, there is little evidence that ecosystem service constraints were behind the decline of the Greek, Roman, Inca, or Ming Chinese civilizations, to name but a few. In other cases, ecosystem service reduction may have been a contributory factor, but either its role is not fully established or its relationship to other factors is unclear (Tainter 1988, 1995). For example, the three main Egyptian dynastic periods and their intervening periods of collapse correspond closely with periods of above and below average flow of the Nile river (Bell 1971; Butzer 1984).

There are also historical examples of societies that have culturally evolved so as to live in balance with their natural resource base over a long period of time. (See Chapter 11 for an example from the highlands of Peru; see also examples in Diamond 2005.)

Failure of ecosystem services is thus implicated in many societal collapses in the past, but not all. As Diamond (2005) points out, the critical issue is how a given society chooses to respond to the signals of emerging problems.

real, is the benefit that urban people gain from both their local urban ecosystem (for instance, the amelioration of microclimate provided by plants in cities) or from the existence of food-producing and other ecosystems far from where they live. There are many types of ecosystem services, and several ways to classify them. The MA divides these into provisioning services, regulating services, supporting services, and cultural services, each of which has several sub-categories. (See Chapter 1.) Most MA sub-global assessments used these concepts but some, such as Vilcanota or Bajo Chirripó, adopted local concepts of ''ecosystem services.''

Biodiversity is a special case: in some respects it is an ecosystem service, and in other respects it is not. The distinction is subtle but important, and remains a source of much confusion, partly because the word ''biodiversity'' is often used outside the MA as a synonym for ''life on Earth.'' Certainly, *all* ecosystem services require the existence of living organisms for their delivery, but in many cases it is not the *diversity* of the organisms that is important, but the presence of a viable population of at least one species representing a particular functional group. For example, a well-regulated hydrology requires plant cover, but there is no a priori reason to suspect that low-diversity vegetation would perform this function differently from high-diversity vegetation, if it had comparable leaf area, height, and stomatal conductance.

On the other hand, there are many cases where the *diversity* itself is essential to the service; such cases use the term biodiversity in its true sense—referring to the *variety* of genes, species, and ecosystems. For example, nature-based tourism sets out to appreciate diversity, not uniformity, and much other conventional tourism is enriched by the biodiversity encountered incidentally. The delivery of many ecosystem services requires a non-trivial amount of biodiversity, but not necessarily the maximum amount possible in that environment. For example, it is possible to produce food using a single crop cultivar growing in an abiotic nutrient solution, but in the long term, sustained productivity, adaptation capacity, pest resistance, and balanced nutrition depend on the existence of a diverse genetic pool in both the crop plant and the environment that supports it. Nevertheless, even an agro-ecosystem managed for high biodiversity typically has significantly less biodiversity than the native vegetation it replaces. Because of these complexities, the MA has chosen to treat biodiversity in general as an underlying condition that is required, in varying degrees, for the delivery of ecosystem services. Where biodiversity is clearly a service in its own right, it is identified as such.

There are some things related to natural ecosystems and the geophysical forces of Earth that do us harm rather than good. Examples are floods, landslides, and outbreaks of pests and diseases. We would not in normal language call them ''services,'' but the MA does not treat them as a separate class, because the degree of their impact remains sensitive to ecosystem condition. For instance, all floods may be hazardous, but actions that are taken in the upper catchment can cause floods to be less frequent or less severe. This ame-

lioration of an adverse impact is clearly a benefit to society. In some cases, one group of people sees the ''service'' as a benefit, while for others it is a disbenefit. For example, elephants are a boon to tourists, but a bane to small farmers. The MA conceptual framework treats all such examples as ''services,'' even if in some cases the net impact on human populations is negative. This allows the net benefit, or change in benefit, to be assessed. The magnitude of a negative impact can often be altered by human action.

A major reason for conducting the MA simultaneously at several scales, and thus for having regional and local components, is that ecosystem services are scale-, time-, and location-dependent. The interplay between an ecological system and the human sub-systems embedded in it (both of which vary in time and space) means that ecosystem services tend to occupy particular space-time domains with somewhat fuzzy boundaries. At a local scale, a particular fruit may only be produced and consumed in a certain area, and only in certain seasons. At the other end of the space-and-time scale, climate change may occur over large regions and long periods of time.

The delineation of the domain and scope of individual MA sub-global assessments was left to the teams involved in their execution, in consultation with their stakeholders. This process generally involved a congruence of institutional factors (such as political governance boundaries) and biophysical factors (for example, the extent of a watershed). Having agreed on a domain, the user group at that scale then determined the most important ecosystem services to be assessed. Table 3.1 shows the range of the services addressed by a sample of MA sub-global assessments.

3.3 Human Well-being and Its Components

There is widespread recognition that human well-being includes the range of assets and experiences in Table 3.2, adapted from the MA conceptual framework (MA 2003; see also Chapter 1 of this volume). Human well-being has many components, including many aspects *not* based in ecosystem services. Moreover, the components of well-being are experienced and perceived differently across cultures and socioeconomic gradients. (See Chapter 11 for examples of different local perceptions of well-being.)

These components of well-being refer to personal and social functioning, and they express what a person values doing or being (Sen 1999). Well-being also needs to be understood at the supra-individual level, since some aspects of well-being are primarily a collective experience or the property of a community (for example, resilience to ecological shocks or stress). Indeed, the colloquial phrase ''well-being of nations'' reflects this perspective. Nevertheless, research—especially the *Voices of the Poor* study conducted in 23 countries (Narayan et al. 1999; Narayan et al. 2000)—has shown that poor people consistently stress that well-being depends primarily on having the ''basic material minimum requirements for a good life,'' and they attach particular importance to secure and adequate livelihoods that enable them to provide for their children. The well-being of humans, as social beings, requires a society with a sufficient amount of social, human, and natural capital, as well as manufactured (that is, conventional economic) capital. Within ethnically and economically complex human cultures, trade-offs and exchanges occur among these types of capital. For example, the accumulation of manufactured capital is often achieved at the cost of natural capital, and sometimes at the cost of social capital. In the longer term, however, the stocks of all these forms of capital depend on the continuing flow of services from the natural world. In this sense, nature is the true ''creator'' to whose products human societies seek to add economic and cultural value, so as to suit the needs and purposes of society.

The management of shared natural resources poses particular institutional challenges that have been solved in different ways at various times and places. One common response is regulation to prevent abuse and free-riding; Hardin refers to ''mutually agreed mutual coercion'' (Hardin 1968). Another response is the process of enclosure and privatization. There is growing evidence that these are not the only effective approaches, and may not always work (Dietz et al. 2003). Since the early 1990s, there has been a worldwide proliferation of community-based groups seeking sustainable management of river basins, forests, irrigation systems, pests, wildlife, and fisheries (Pretty 2003). This indicates the potential for environmentally directed social capital to achieve a sustainable flow of ecosystem services.

The relationship of ecosystems and their services to human well-being is complex, and may change over time. Some ecosystem changes are planned, but many are the inadvertent result of other human activities—and these in particular may harm and impoverish people who are already disadvantaged. The sustainable well-being of a community at large depends on the continued flow of ecosystem services, and on the distribution of benefits and costs. Further, in an increasingly interconnected world, those gains and losses may be experienced at great distance in both space and time. Hence a further important criterion of well-being is the capacity to adapt in situations of change, and to do so without compromising the well-being of others, either now or in the future.

The MA used a range of methods and approaches to assess well-being. Some MA sub-global assessments used indices: for example, the assessment of Coastal British Columbia in Canada constructed an index of human well-being with 49 different indicators selected by experts and stakeholders (Coastal BC). Others used standalone indicators for each of the components of well-being, like the assessment of San Pedro de Atacama in Chile. Some used both indices and indicators, such as the Southern Africa Gariep Basin assessment (SAfMA Gariep), which used the Human Development Index developed by UNDP and socioeconomic indicators such as GDP per capita, unemployment rates, the Gini coefficient, primary school enrolment, life expectancy, and the age dependency ratio. Still others, in particular local level assessments, assessed well-being as perceived by the communities involved: Trinidad's Northern Range, the Bajo Chirripó in Costa Rica, and Sistelo in Portugal are examples of such assessments. Different criteria for well-being were identified by different communities; in

Table 3.1. Ecosystem Services in Selected MA Sub-global Assessments. This table reflects the individual sub-global assessment teams' own evaluations of how comprehensively they assessed services. The data were collected at the Knowledge Market session at the meeting of the Working Group in Alexandria, Egypt, in March 2004. (See Box 2.1 for a description of the "knowledge market" process.) Key: + + + = assessed comprehensively, + + = moderately assessed, + = slightly assessed. X = important to stakeholders, but not assessed.

Sub-global Assessment	Food, incl. Livestock and Fish	Water Supply	Fuel and Energy	Biodiversity-related	Carbon Sequestration	Fiber and Timber	Runoff Regulation	Cultural/ Spiritual Amenity	Other
San Pedro de Atacama	+	+ + +		+ +			+ +	+ + +	astronomical observation, minerals
Caribbean Sea	+ + +	+ +	+	+ + +				+ + +	shoreline stabilization, coastal water quality
Coastal BC	+ +			+ + +		+ + +	+	+ +	
Tropical Forest Margins	+ + +	+ + +		+ + +	+ + +	+ + +	+ +	+	nutrients, trace gases, grazing, pest control, air quality
India Local	+ +	+ + +	+ + +	+ + +		+ + +	+ +	+ + +	non-wood forest products (e.g., bidi leaves *Diospyros mespiliformis*)
PNG National	+ +	+ +	+	+ + +		+ +	+ +	+ + +	
PNG Local	+ + +	+ + +	+ +	+ +		X	+ + +	+ + +	gold
Laguna Lake Basin	+ + +	+ + +		+ + +	+ +			+	greenhouse gases
Portugal	+ + +	+ + +		+ + +	+ + +	+ + +	+ + +	+ +	primary production, erosion control
SAfMA	+ + +	+ + +	+ + +	+ + +				+ +	air quality, desertification
SAfMA Gariep	+ + +	+ + +	+ +	+ + +			+	+ +	minerals, air quality
SAfMA Livelihoods	+ + +	+ +	+ + +	+ + +		+ +	+ +	+ +	medicinal plants
SAfMA G–M	+ + +	+ + +	+ +	+ +		X	X	+	landscape importance
SAfMA Zambezi	+ + +	+ + +	+ +						
Sweden KW	+ + +	+ +		+ + +		+	+ + +	+ + +	filtering of nutrients, ecotourism
Sweden SU	+	+		+ + +	+ + +	+	+	+ + +	noise reduction, air quality, ecotourism
Northern Range	+ +	+ + +		+ +	X	+ +	+ + +	+ + +	land space for living
Mekong Wetlands	+ + +	+ + +	+	+ + +	+	+	+ + +	+	medicinal plants
Western China	+ + +	+ + +		+ + +	+ + +		+		desertification, soil erosion
Bajo Chirripó	+ +	+ + +		+ + +		+		+ + +	medicinal plants
Colombia	+ + +	+ + +		+ + +				+	
Eastern Himalayas	+	+ + +	+ +	+ +				+	
Sinai	+ + +	+ + +	+	+ + +			+ + +		medicinal plants, grazing
India Urban	+ +	+ + +	+ +	+ + +	+ +			+	human wildlife conflict, waste recycling
São Paulo	+ + +	+ + +		+ + +	+ +	+ + +	+ + +	+ + +	microclimate regulation, air pollution control, disease control, space
Altai-Sayan	+ +	+	+	+ + +		+ + +		+ + +	medicinal plants, habitat

Table 3.2. Components of Human Well-being. Well-being depends substantially, but not exclusively, on ecosystem services. The top-level categories are general, while the sub-elements relate specifically to the contribution by ecosystem services.

Security[a]
a safe environment
resilience to ecological shocks or stresses such as droughts, floods, and pests
secure rights and access to ecosystem services
Basic material for a good life
access to resources for a viable livelihood (including food and building materials) or the income to purchase them
Health
adequate food and nutrition
avoidance of disease
clean and safe drinking water
clean air
energy for comfortable temperature control
Good social relations
realization of aesthetic and recreational values
ability to express cultural and spiritual values
opportunity to observe and learn from nature
development of social capital
avoidance of tension and conflict over a declining resource base[a]
Freedom and choice
the ability to influence decisions regarding ecosystem services and well-being

[a] Extreme breakdown of social relations can deteriorate into armed conflict, and thus in some cases could be considered an aspect of the security component of well-being.

BOX 3.2

Human Well-being as Perceived by Selected Communities Assessed

In the *Gariep Basin of Southern Africa,* different communities identified different criteria for well-being. For example "not being vulnerable" was an important criterion for people in Sehlabathebe, "self-determination" featured strongly as a criterion in the Richtersveld and the Great Fish River sites, and communities' sense of belonging was more important than cash in the Kat River Area. In each of the three communities, livestock ownership was a significant indicator of wealth (SAfMA Gariep).

In *Trinidad's Northern Range,* aspects of human well-being as perceived by the communities included income security (for example, an income that is based on regular and predictable employment), access to fresh water of good quality and quantity, security of land tenure, availability of affordable housing, recreational opportunities, personal security, and sense of place (Northern Range).

In *Sistelo, Portugal,* nearly forty different criteria for human well-being were identified using participatory approaches. The most cited criteria were: cash income, access to goods and services, assets (house, cattle, and fields), food quantity, health, leisure, age, capacity to work, not being alone, mutual help, conviviality, joy, security through retirement pensions, safe environment (air and water quality), and tranquility. Freedom from dependence on local provisioning services was considered a major improvement in the well-being of the community (Portugal).

Criteria for well-being in *Bajo Chirripó, Costa Rica,* were assessed in participatory workshops. Different groups in the same community identified different criteria. Elders identified species abundance, respect for their territory, preservation and development of the indigenous culture and adequate use of natural resources as main determinants of their well-being. Women identified seven needs: forest preservation, medicinal plant conservation, adequate use of natural resources, family respect, water conservation, employment and indigenous culture. Young men considered as important for well-being having their own house, employment, forest conservation, cultural respect, giving love and charity, water conservation and education (Bajo Chirripó).

Bajo Chirripó, elders, women, and young men all perceived well-being differently. (See Box 3.2.) Considering that well-being is context-dependent, it is not surprising that indicators and criteria vary across different situations.

All indicators used to measure human well-being have limitations. For instance, GDP data are normally readily available from national and international sources by sector on a historical basis, thus enabling measurement over time. But they often fail to include important non-marketed goods and services and neglect income distribution and natural capital depletion, which are also important for material well-being. For this reason, the MA assessments never used GDP per capita by itself as a proxy for material well-being, although many sub-global assessments used GDP data to assess the contribution of ecosystem services to the production of economic goods and services.

Equity—that is, a more equal distribution of well-being among people or "equality in the capability (or freedom) of different individuals to pursue a life of their choosing" (World Bank 2004)—is an important issue. Averages often hide large disparities in distribution. Some assessments tried to address this issue by using inequality measures, like the Gini coefficient (SAfMA Gariep) and the disaggregation of indicators by location (for example, urban versus rural, as in the Colombia assessment), or by gender or indigenous status (Coastal BC). Thus another reason why assessments of well-being at different scales are important—equity and inequity in access to services are often more evident at less-aggregated scales.

The selection of the indicators best suited to assess well-being in a specific context is crucial. Both the set of indicators used, and the way they are measured, influence the findings. Comprehensive assessments of well-being should address the multidimensional and specific nature of well-being, using multiple indicators and a combination of quantitative, qualitative, conventional, and participatory methods.

The aspects of human well-being assessed by a range of sub-global assessments are shown in Table 3.3. Although the assessments recognized the multidimensional character of human well-being, individual assessments did not exam-

Table 3.3. Components of Human Well-being in Selected MA Sub-global Assessments. This table reflects the individual sub-global assessment teams' own evaluation of how comprehensively they assessed the various components of human well-being. The data were collected at the Knowledge Market session at the meeting of the Working Group in Alexandria, Egypt, in March 2004. (See Box 2.1 for a description of the "knowledge market" process.) Key: + + + = comprehensively assessed, + + = moderately assessed; + = slightly assessed.

	Security			Health				
Sub-global Assessment	Clean, Safe Environment	Resilience against Physical Hazards	Basic Material for a Good Life, incl. Income	Nutrition	Infectious Diseases	Other	Good Social, Cultural, and Spiritual Relations	Freedom and Choice
San Pedro de Atacama	+ +		+ + +	+	+		+ + +	+
Caribbean Sea	+ +	+ +	+ + +	+	+ +		+	+
Coastal BC	+		+ + +				+ + +	+ + +
Tropical Forest Margins	+	+	+ + +	+ +	+		+	+ +
India Local	+ +	+ + +	+ + +			first aid	+ + +	+ + +
PNG National	+	+ +	+ + +	+ + +	+ +			+ +
PNG Local	+ + +	+ +	+ + +	+ + +	+ + +		+ + +	+ +
Laguna Lake Basin	+ +	+	+ +				+	+ +
Portugal	+ +		+ + +			respiratory disease	+ +	+ +
SAfMA Regional	+		+ + +	+ + +	+		+ +	+
SAfMA Gariep	+		+ + +	+ + +		AIDS		+
SAfMA Livelihoods	+ +	+	+ + +	+ +			+ +	
SAfMA G–M			+ + +	+ +				
SAfMA Zambezi			+ + +			+ +		
Sweden KW	+	+ + +	+ + +	+ +			+ + +	+ + +
Sweden SU	+					stress relief, exercise		
Northern Range	+	+ +	+ +		+		+ +	+
Mekong Wetlands	+ +	+	+ + +	+	+		+ +	+ + +
Western China		+	+ + +	+				+ + +
Bajo Chirripó	+ + +	earthquakes	+ + +	+ + +	+ + +	parasites	+ + +	+ + +
Colombia			+ + +	+ +	+ + +	+ +	+ +	
Eastern Himalayas			+ + +	+			+ + +	+ +
Sinai	+	+	+ +				+	
India Urban	+ +		+ +				+ +	+
São Paulo	+	+ + +	+ + +	+ +	+ +	+	+ +	+ +
Altai-Sayan	+ +		+ + +	+			+ + +	

ine all the dimensions of human well-being, and individual components of well-being were assessed to varying degrees of detail. Sub-global assessments tended to concentrate on those measures of well-being that are easier to quantify, particularly those associated with income.

There are several problems with assessing and attributing the links between ecosystem services and well-being. One is multiple causality: for example, human health depends on health services, education, *and* ecosystem services (and, often, several other factors as well). Thus an improvement in health, as measured by rising life expectancy, could occur in the face of a moderate decline in ecosystem services, if other factors were positive—including the efficiency of conversion of ecosystem "capital" to human "income." Sub-global assessments used indicators of well-being that frequently go beyond those linked directly and exclusively to ecosystem services: for example, average years of schooling and the literacy rate. Other indicators, such as under-five mortality, are more closely (but still not exclusively) linked to ecosystem services, in this case, clean water and adequate nutrition.

There are also issues of spatial and temporal scale. Whose well-being should be assessed? The well-being of people living in the place where a service is provided (the origin), or the well-being of those who benefit from this service? A related problem concerns intergenerational assessment, leading to ''undemocratic democracy—the lack of democratic representation of future people'' (Chambers and Conway 1991).

3.4 Links between Ecosystem Services and Human Well-being

Human well-being is affected by changes in the composition and functioning of ecosystems and the resultant flow of ecosystem services. Often-used terms such as ''ecosystem health'' or ''ecosystem integrity'' gain much more focus when defined in terms of the capacity of ecosystems to supply a particular basket of services to users of those services. Worldwide evidence of escalating human impacts on ecosystems raises questions about their capacity to continue to provide the services necessary for an acceptable level of human well-being. Human activity already impairs the flow of many ecosystem services. If current trends continue, humanity will markedly alter virtually all of Earth's remaining natural ecosystems within a few decades (Vitousek et al. 1997), in most cases in ways that increase the supply of one service (such as food or fiber) at the expense of others (for example, clean water and self-regulation of pests and diseases).

Human transformation of ecosystems and the choices about the ways in which their services are used can either amplify or reduce the benefits to society. For example, conversion of wetlands and forests to croplands helps to ensure stable food supplies, but it also causes pollution of waterways, disruption of hydrology, reduced fish yields, loss of biodiversity, and loss of scenic places. The value of the services lost to human society in the long term may exceed the short-term economic benefits that are gained from those transformative activities. Ecosystem transformation is undertaken, of course, because of real or anticipated benefits that will accrue at least in the short term. Indeed, our present societies are dependent on such transformation. Agriculture, forestry, and fishing provide one in every two jobs worldwide; and crops, timber, and fish contribute more to the global economy than do industrial goods (World Bank 1999). The key question is how to understand and quantify the current and future benefits, costs, and risks involved in all cases. There is much human well-being at stake, both now and in the future.

Mining in Papua New Guinea provides an example of the complex links between ecosystem services and human well-being. Mining involves the localized loss of agricultural land, plantations, and coral reefs, which are compensated for with cash handouts by the mining companies. In addition to replacing the lost services (perhaps not completely), the cash can also be used to obtain services not previously available, such as improved forms of housing, piped water supply systems, high-protein foods, western medicines, and other forms of health care, with dramatic increases in well-being. Nevertheless the loss of provisioning and regulating services usually tends to outlast the cash benefit. There are also important social impacts (for example, social disintegration and loss of spiritual values connected to a ''sense of place'') that decrease well-being in important ways. At Lihir, the spatial extent of the environmental impact of the mining operation is small, and the cash benefits are felt over a large area. As a result, there can be net increases in cash benefit (through employment and other spin-offs) in areas where there is no loss of ecosystem services (PNG).

Changes to ecosystems, and thus to human well-being, can occur at global, regional, sub-regional, national, and local scales, and often at several scales simultaneously. For example, fishing activities in the Caribbean Sea, which contribute a substantial portion of the region's GDP as well as providing jobs and protein to many people, can be analyzed at the fishing community scale, the national scale, the sub-regional scale, the regional scale, and the scale of the entire North Atlantic Ocean. Institutions exist for regulating the use of the service at all these scales, and failure of these institutions has impacts on the scales above and below it (Berkes 2004).

Indigenous peoples, that is, people who have lived within the context of a particular ecosystem for many generations, represent a special case of ecosystem service-well-being linkage. (See Chapter 11.) Not only does their ''sense of place'' figure overwhelmingly within their worldview, but when the ecosystem services they depend on decline, they may have few options to replace these with services from other sources. Furthermore, indigenous people are frequently politically marginalized and thus excluded from decisions that affect resources that they have used, and often protected, for centuries.

The set of linkages between ecosystem services and human well-being selected for study in particular sub-global assessments varied according to the different user needs in those assessments. Some local assessments, like those in the Vilcanota, Peru, assessment and in Sistelo in the Portugal assessment, also tried to assess how the communities perceive these links and which ecosystem services are most valued by them. In the Portugal assessment, a landscape with cultural and aesthetic value at the national scale—*socalcos* or cultivated terraces at successive heights on the mountain slopes—is seen by locals as having many disadvantages. In fact, most people agreed that a hypothetical scenario involving leveling the terrain would improve well-being (Portugal).

The examples in this volume (especially in Chapter 8) and elsewhere in the MA documentation illustrate the nature and extent of the connection between ecosystem services and human well-being, and the multiple scales at which the relationships exist. Clearly these links involve trade-offs (see the following sections). This section illustrates some of the links, mainly with examples from sub-global assessments; it is not meant to be exhaustive.

3.4.1 Provisioning Services

3.4.1.1 Fisheries as a Source of Food

Fisheries are an important source of food, employment, and income. Globally, marine fish and shellfish production has increased six-fold, from 17 million tons in 1950 to 105 million tons in 1997 (FAO 1999). This rapid growth has come in part from aquaculture, which in 2000 accounted for 27.3% of the total marine plus freshwater harvest (FAO 2002). Fish provide one sixth of the total animal protein and 6% of all protein consumed by humans (Laureti 1999). Fishing and aquaculture provided jobs for almost 35 million people worldwide in 2000 (FAO 2002), the vast majority of whom are in developing countries.

The Caribbean region, like other island systems, is particularly dependent on fishing. The number of people working in the fishing industry there increased from nearly 200,000 in the 1970s to over 500,000 in the 1990s, with half as many again employed in the secondary sectors (processing and marketing, boat building, net making, and other support industries). Moreover, it is estimated that each person working in the fisheries has five dependents; thus the total number of persons who are dependent on the Caribbean Sea for their living is approximately 1.5 million. Average per capita supply is 19 kg, which is well above the world average. Fish consumption in several of the small island states exceeds local production. In 2000, imports of fish and fishery products to the region were approximately 360,000 tons valued at $410 million, whereas exports was approximately 200,000 tons valued at $1.2 billion (Caribbean Sea; Agard and Cropper 2003).

In the Lihir Islands of Papua New Guinea, fish consumption represents about 10% of the recommended daily protein intake. Since the start of mining operations nearby, the consumption of fresh fish and marine invertebrates has increased slightly (Brewer et al. 2003, cited in PNG), but paradoxically, the pressure on local fish resources has not. Although the increasing availability and affordability of modern fishing gear due to the increase in cash income from mining would suggest increased local fishing activity, in practice more fish and other protein sources are now imported. The local fishery occasionally experiences a limited form of management because of the association of spiritual values with coral reefs and resultant restrictions on fishing activities

3.4.1.2 Fresh Water

The supply of usable fresh water will be a major challenge in the twenty-first century in many parts of the world. Globally, largely reflecting population growth, the amount of water available per person has decreased from 16,800 cubic meters per person per year in 1950, to 6,800 cubic meters per person per year in 2000 (Shiklomanov 1997; UNDP et al. 2000). More significant, one third of the world's population lives in countries experiencing moderate to high water stress, and this fraction is increasing as population and per capita water demand grow. The main consequences are negative impacts on food production, sanitation, and economic development (Hinrichsen et al. 1998), directly affecting material well-being and health.

Access to clean drinking water is a basic human need that, if not satisfied, can have several impacts on health. Lack of access to safe water supply and sanitation results in hundreds of millions of cases of water-related diseases and more than 5 million deaths every year (UNEP 2002). Water cleansing is an important service naturally provided by ecosystems. The Kristianstad Wetlands in Sweden provide ecosystem services related to fresh water, including retention and removal of dissolved substances, uptake of metals, bacterial removal, dilution of pollutants, soil wetting and fertilization, recharge and discharge of groundwater, reduced downstream damage, and avoidance costs of engineering structures (Sweden KW).

Water shortages can also have negative impacts on social relations and the security dimensions of well-being. The Salar de Atacama in Chile is a salty wetland within the driest desert in the world. Surface water is limited. The current major concern is over groundwater usage, and the extent to which its exploitation is sustainable. The economic activities in this region include mining, agriculture, and tourism, all of which depend on the quantity and quality of available water. The Salar de Atacama holds over 40% of world lithium reserves; mining provides 12% of the local employment and two thirds of the regional GDP. It also consumes 65% of the water used in the region. Tourism is the second largest source of employment and income, and needs fresh water for its facilities. Local communities rely on water for subsistence agriculture and raising livestock. Two thirds of subsistence farmers do not have enough resources to buy water rights when bidding against the mining companies. Hence the shortage of water is generating major conflicts over access and ownership rights among the competing users (San Pedro de Atacama).

Conflicts between local people and mining companies for water were potentially an issue for the people in the Lihir Island Group, Papua New Guinea. They depend for drinking water on creeks, springs, and rainwater collection and storage. In the northeast of Niolam, the gold mining company and its employees consume a significant amount of fresh water, but conflict has not arisen because the mines have new techniques for water extraction and storage (PNG).

Islands of the Caribbean Sea provide another example of how the introduction of new technology can alleviate an ecosystem service constraint. The available runoff in many islands in the region is inadequate to satisfy the demand for fresh water, so about 667,053 cubic meters per day is produced by desalinization of seawater. The cost of desalinization is about $317 million per year (Caribbean Sea; Agard and Cropper 2003).

3.4.1.3 Woodfuel and Charcoal

Woodfuel, one of the services supplied by forests and woodlands, is the main way in which the basic human needs for heating, cooking, and boiling water are satisfied in places where other sources of energy are unavailable or unaffordable. Even in highly industrial nations such as Swe-

den and the United States, wood supplies 17% and 3% of total energy consumption, respectively. Wood provides more than half the energy consumed in developing countries; in some African countries, such as Tanzania, Uganda, and Rwanda, it accounts for 80% (SAfMA Regional; Scholes and Biggs 2004). In the Kafue basin of Zambia, wood provides 96% of household energy consumed; in rural areas, 95% is consumed in the form of firewood, while in urban areas, 85% is in the form of charcoal. Shortage of woodfuel occurs in areas with high population density without access to alternative and affordable energy sources. In those provinces of Zambia where population densities exceed the national average of 13.7 persons per square kilometer, the demand for wood has already surpassed local supply. In such areas, people are vulnerable to illness and malnutrition because heating homes is too expensive, cooking food is not possible, and consumption of unboiled water facilitates the spread of waterborne diseases such as cholera. Women and children in poor rural communities are the most affected by woodfuel scarcity. They must walk long distances searching for firewood, and therefore have less time for tending crops, cooking meals, or attending school.

3.4.1.4 Biological Products

Billions of people around the world depend partly or fully on products collected from ecosystems for medicinal purposes. Some 75% of the world's population rely on traditional medicine for primary health care and 42% of the world's 25 top-selling drugs in 1997 were derived from natural sources (UNDP et al. 2000). Even when synthetic medicines (which themselves often originated from natural sources) are available, the need and demand for wild products persists. For example, although the development of a mining economy in the Lihir Island Group of Papua New Guinea has increased the availability of modern drugs and medical treatment, local people still widely use traditional medicines. Most medicinal plants used among these people are actively cultivated. Lime, which is made from coral, is a central ingredient in many traditional medicines. It is mixed with various medicinal plants to produce a paste that is usually applied as a topical remedy and is also used for alimentary diseases, colds, and pneumonia (Powell 1976; MacIntyre and Foale 2002, cited by PNG).

3.4.1.5 Coffee: An Example of a Natural Product–based Source of Employment and Income

Coffee production is a globally important economic sector especially for producer countries such as Brazil, Viet Nam, and Colombia, where it is a source of employment and income. The coffee-growing region of Colombia encompasses an area of more than 3.6 million hectares. Coffee is grown in 605 municipalities in the country (56% of the national total) and involves 420,000 households and more than half a million agricultural productive units or farms. Around 870,000 hectares are currently devoted to coffee production. This region makes an important and quite stable overall contribution to national gross domestic product (Colombia).

3.4.2 Regulating Services

3.4.2.1 Carbon Sequestration

Human activities are currently responsible for the emission of an estimated 7.9 billion tons of carbon to the atmosphere annually (IPCC 2001). Tropical deforestation currently accounts for approximately one fifth of the net increase in atmospheric carbon dioxide (IPCC 2001; see also MA *Current State and Trends,* Chapter 13.) In general, when forests are cleared, they are replaced by land uses that contain only 2–40% of the carbon originally stored in the forest (Palm et al. 2004). In Africa, clearing of forests accounts for 43% of carbon emissions (Gaston et al. 1998).

Increasing concentrations of carbon dioxide in the atmosphere contribute to climate change, which in turn are likely to affect human well-being through adverse impacts on the availability of fresh water, food production, and the distribution and seasonal transmission of vector-borne infectious diseases (UNEP 2002). Reducing anthropogenic carbon emission is one way to mitigate climate change; another way is to maintain or enhance the capacity of ecosystems to absorb carbon. Forests, while in their active growth phase, are the most effective terrestrial ecosystem for recapturing carbon dioxide, the greenhouse gas contributing most to global warming. Recuperation of degraded lands and soils through improved management or land use change—for example, from traditionally managed pastures to improved pastures or from degraded crop or grasslands to tree plantations and agroforestry—is particularly effective in sequestering carbon and still allowing the harvest of products to benefit the users of such land (Van Noordwijk et al. 2001). For example, the 353,004 hectares of undergrowth and 118,889 hectares of reforestation areas in the Green Belt of São Paulo city, Brazil, balances a large fraction of the carbon dioxide generated by the urban population, while providing other amenity services as well (São Paulo).

3.4.2.2. Water Flow Regulation

Forests provide several valuable services in relation to watershed protection. Tree roots pump water out of the soil, thereby reducing soil moisture and the likelihood of mudslides. Forests moderate the runoff from precipitation, reducing flows during flooding, increasing flows during drier times, and protecting soil from erosion (UNDP et al. 2000). Convincing evidence was found in a Southeast Asian study linking deforestation to increased local risks of flooding (that is, within small catchments) but there are several uncertainties about the basic relationships between rainfall, watershed functions, deforestation, reforestation, and other aspects of land use change in the humid tropics (Tropical Forest Margins; Tomich et al. in press). In Trinidad's Northern Range assessment, a strong link was also established between the services of runoff regulation and water retention and the environmental and economic security dimensions of well-being, based on expert and community opinions (Northern Range).

The Mekong is the world's twelfth longest river, stretching nearly five thousand kilometers from its source on the Tibetan plateau to its outlet on the coast of Viet Nam. All

the states within the basin, which includes both the richest and poorest nations in Southeast Asia, are keen to promote economic development using the Mekong's water resources. For example, less than 5% of the hydroelectric power potential of 30,000–58,000 megawatts has so far been exploited (MRC 1997). By 2020, the demand for electricity in the Mekong region could be six times greater than in 1993 (MRC 1997). The attainment of this potential is dependent on maintaining the regulating and sediment control functions of the headwater catchments. Full development of this potential will inevitably have some adverse consequences on downstream services, such as the burgeoning fisheries of the Mekong delta.

3.4.2.3 Regulation of Infectious Disease in Humans and Domestic Plants and Animals

Ecosystem transformation may affect the spread of diseases with important impacts on human health. In the village of Koyyur in India, deforestation caused canopy gaps in the rainforest. This initiated growth of grasses and other fodder species, attracting cattle from the villages. These cattle carry ticks that transmit a monkey fever (Kyasanur Forest Disease), resulting in an increase in the disease in humans (India Local).

Decreased diversity in agroecosystems increases the risk of pest attack (Tropical Forest Margins; Landis et al. 2000), with adverse impacts on food production. Simplification of the ecosystem, for instance by the indiscriminate use of broad-spectrum pesticides, decreases the diversity of natural competitors and predators of the problem organism. Pesticides also have negative effects on non-target beneficial organisms, including pollinators and beneficial soil biota (Swift et al. in press). In many cases, an acceptable level of control of pests and diseases can be achieved with a reduced use of pesticides. In some cases, pesticides can be eliminated altogether by the use of natural parasites and predators (Tropical Forest Margins).

3.4.3 Cultural, Spiritual, and Recreational Services

Cultural services may be less tangible than material services, but they are nonetheless highly valued by people in all societies. People obtain diverse non-material benefits from ecosystems. These benefits include recreational facilities and tourism, aesthetic appreciation, inspiration, a sense of place, and educational value.

Many traditional cultural practices linked to ecosystem services have an important role in developing social capital and enhancing social well-being. In a participatory community assessment conducted in Sistelo, Portugal, people reported a worsening of some criteria of local social well-being such as joy, conviviality, and mutual help (Portugal; Pereira et al. 2004). This deterioration was in part linked to the abandonment of traditional agricultural practices such as gatherings of people to work in one another's fields and to accomplish some production activities such as *fiadas* (spinning wool) and *desfolhadas* (stripping of corn leaves). At the same time, this community also reported an improvement in criteria related to material well-being, mainly because of access to new income sources such as retirement pensions and remittances.

3.4.3.1 Nature-based Tourism and Recreation

Recreation and nature-based tourism are important sources of income and employment in many places around the world. The total value of international tourism exceeds $444 billion (World Bank 1999). Nature-based tourism (sometimes called environmental tourism or ecotourism, although strictly speaking, the latter is a subset of nature-based tourism and includes certain ethical considerations) may comprise 40–60% of this total. In Costa Rica, tourism generated $654 million in 1996, and in Kenya, $502 million in 1997. In both cases, most visitors are attracted to the natural assets of those countries. Prior to the outbreak of civil war in Rwanda, tourist visits provided $1.02 million, which enabled the government to protect mountain gorillas and their habitat in the Volcanoes National Park, creating employment for local residents (Gossling 1999). In southern Africa as a whole, nature-based tourism is estimated to generate $5 billion per year, growing at a rate several times higher than that of other natural resource–based activities (SAfMA Regional; Scholes and Biggs 2004).

The Caribbean is probably the most tourism-dependent region in the world. In 2003, the Caribbean travel and tourism economy directly and indirectly accounted for nearly 2 million jobs (one out of every eight jobs), 13.0% of GDP, and a sixth of the export earnings (World Tourism and Travel Council 2003, cited in Caribbean Sea).

The recreational benefit from nature also contributes to the health and social relations dimensions of well-being, as there is a correlation between green areas, good air quality, and human health. The National Urban Park in Stockholm, Sweden, for example, has an estimated 15 million visitors per year, most of whom visit the park for recreation purposes. More than 90% of the urban population in Stockholm visits the city's green area at least once a year, and about half of those visit at least weekly (Wiren 2002, cited by Sweden SU). Recreation in this park system promotes physical exercise and mental well-being. The green area allows humans to come into contact with nature and provides a resource for natural science teaching. The park has several teaching facilities specializing in nature-related subjects (Sweden SU).

3.4.4 Supporting Services

3.4.4.1 Soil Formation

Soil provides essential services such as nutrient cycling (the basis of soil fertility) and water retention. Deforestation and other land uses affect the physical, biological, and chemical properties of the soils, and thus their capacity to supply these services. There is evidence of disproportionate erosion rates on compacted surfaces such as roads, paths, tracks, and human settlements. Data from northern Thailand indicate that unpaved roads produce as much sediment as agriculture, even though these roads occupy less than one tenth of the area occupied by agriculture. Later stages of compaction may lead to runoff without much soil loss, but surface flows

may pick up soil as soon as they pass over soil elsewhere with a higher propensity to erosion (Tropical Forest Margins).

3.4.4.2 Pollination

Pollinators contribute greatly to the production of food and other agricultural goods, and therefore to human material well-being and health. It is estimated that 90% of all flowering plants would not exist without animals and insects transporting pollen from one plant to another (UNDP et al. 2000). Pollinators also provide a recreational service by pollinating backyard gardens. Pollinator declines affect both total harvest and harvest quality (Allen-Wardell et al. 1998, cited by Sweden SU).

The Himalayan region, which extends from China to Afghanistan, is rich in honeybee diversity. It hosts five indigenous and one exotic bee species. Indigenous honeybees play a significant role in pollinating field crops and wild plants, thereby increasing productivity and sustaining ecosystem functions. People in the region recognize that bees help secure better livelihoods, both by increasing agricultural productivity and by generating direct income from selling honey and wax. Apples are a leading cash crop in the region, accounting for 60–80% of total household income. Annual production is estimated at more than 2.5 million tons, valued at about $450 million. In the early 1980s, market demand for particular types of apples altered traditional farming practices, causing farmers to uproot pollinator varieties and plant new, sterile cultivars. The pollinator populations were also negatively affected by excessive use of pesticides. The result was a reduction in overall apple productivity and local extinction of many natural pollinator species (Partap and Partap, 1997 and 2000).

3.4.4.3 Grazing: The Sustained Production of Forage

Grazing by domestic livestock and wild ungulates is the foundation of most human livelihoods in the arid and semiarid parts of the world, which together constitute about a quarter of the global land surface. Bedouins constitute the majority of people living in the Sinai Peninsula. Grazing supports a long list of services that contribute to the well-being of Bedouins; it permits their survival in this harsh desert environment. The services include meat and milk, meeting Bedouins' need for protein; transport, which is entirely dependent on camels; weed control by sheep in orchards; manure for fertilizing crops; animal skins for tents; and wool from camels, sheep, and goats for a variety of household and farming necessities. Wool is also the backbone of handicraft industries such as carpet weaving (Dames and Moore 1985).

3.5 Trade-offs and Congruence between Services

Typically, ecosystems deliver multiple benefits at the same time, from the same place. For example, the forests of Portugal simultaneously provide timber products (wood and cork), non-wood products (resins, honey, fruits, wild mushrooms, aromatic and medicinal plants, game, fodder, and acorn and woodland production), and other ecosystem services (recreational use, carbon sequestration, water resource protection, and environmental protection), approximately in the ratio of 3:2:1, in terms of economic value (Mendes 2004, cited by Portugal).

Some services can be delivered simultaneously from the same system or landscape without mutual interference, while others are partly or fully antagonistic. Services that have compatible landscape management needs can be referred to as "congruent." Decisions about the transformation and exploitation of ecosystems often pose difficult choices. There are typically trade-offs to consider between benefits and risks, gains now versus other types of gains in future, and gains to some persons accompanied by losses to others. Who should make such decisions, and how?

Consider, for example, the draining of swamps, which may reduce mosquito-borne infectious disease risks while at the same time destroying the wetland system and its flow of ecosystem services. Similarly, creating roads within forests facilitates contact with, and movement of, infectious diseases such as malaria and viral hemorrhagic fevers, while also providing remote communities with access to health care and to other facilities. Trade-offs can also occur over time. In Sri Lanka, for example, the clearing of tropical forest for agriculture initially reduced the habitat for forest-adapted anopheline mosquito vectors of malaria. However, in due course, other vector species occupied the changed habitat, thereby contributing to the resurgence of malaria (McMichael 2004).

An historical perspective may assist in understanding the interplay between a changing flow of ecosystem services, including trade-offs between them, and the resultant human consequences. (See Chapter 11.) This perspective takes account of slow biophysical (and often lagging) social processes. It emphasizes a dynamic rather than a static view of both development and the most-valued ecosystem services at various stages. The topic of trade-offs between ecosystem services is more comprehensively treated in Chapter 8.

3.6 Trade-offs between Ecosystem Services and Human Well-being

It does not necessarily follow that more ecosystem services mean more human well-being, or vice versa. It is, for instance, quite widely observed that general improvements in well-being often occur *despite,* or because of, decreases in ecosystem services, at least at the local scale. The Colombia assessment, for example, found high levels of biodiversity correlated significantly with high levels of unsatisfied basic needs and low levels of quality of life (Colombia; Rincon et al. 2004). The reasons for the complexity in the relationship are several.

First, human well-being has many contributory factors, only some of which are ecosystem-related. The concept of total capital may be helpful here (Dasgupta 2001). Total capital consists of natural capital, human capital, social capital, and manufactured capital. These forms of capital are partly substitutable for one another. Net human well-being improvement requires total capital to increase, which may

be possible even if one or two components decrease, provided that the others increase sufficiently to balance the decline. The loss of a particular source of ecosystem service can be replaced with other sources, using the income derived either from the exploitation of natural or human capital or from the growth of manufactured capital. In this sense, development enhances freedom of choice (Sen 1999) and corresponds to an improvement in well-being. However, increases in net human well-being and total capital at scales greater than the single individual may well involve declines in well-being for particular individuals, because average measures of performance may not reflect regressive distributional impacts; this raises moral and practical problems involving who decides which trade-offs are acceptable. Furthermore, substitution may be a rational choice for humans, but there may be no substitutes for some ecosystem services. Can the complex interactions within and between ecosystems, especially those that produce regulating services, be ''substituted'' by human controls? Currently, the answer is certainly no.

Second, immediate improvements in well-being may occur at the expense of deferred environmental costs. An example is the accumulation of waste typically resulting from the rising consumption levels that follow increases in wealth. The waste products may not be an immediate problem, but may eventually exceed the limits of human tolerance or ecosystem absorptive capacity. The tolerable limit tends to be lower in population settings of poverty where, often, waste-absorbing environmental resources have already been overused.

Third, the widening geographical reach of communities that usually accompanies increases in well-being enables them to obtain the services they need from non-local sources. For example, in the broad sweep of history, urbanization is usually associated with improved well-being. At the same time, urban areas rapidly exceed the capacity of their immediate environment to supply their needs for food and water. They are nevertheless able to continue to grow, because the economic power of the city enables it to satisfy these needs from distant locations. The globalization of trade has progressively increased the disconnect between benefit and impact. The capacity to satisfy continuously growing local needs by unsustainable harvest from distant sources may now be reaching its limits, as the combined ''footprint'' of human settlements all around the world approaches and, in some cases, possibly exceeds the total area available for service delivery (Wackernagel and Rees 1996).

The issues of limits to substitution, thresholds of human tolerance or ecosystem absorptive capacity, and limits of ecosystem capacity to provide the needed services raise an important, but not yet answered, question: When does the relationship between ecosystem services and human well-being cease to be characterized by trade-offs, and instead is characterized by unambiguous net loss?

A conceptual framework for understanding the variable, and often apparently contradictory, relationship between ecosystem service level and human well-being is illustrated in Figure 3.1. There are plausible cases where an ecosystem service increases continuously as well-being increases, for instance as a result of the successful implementation of agricultural or sanitary technology. At a global scale, there is now greater food security than at any time in the history of the world. Most parts of the world have registered continuous improvement in yields per hectare and food supply per capita throughout their developmental history (Bruinsma 2003). There are some notable regional exceptions. As the scale of analysis becomes progressively more local, the issue of (in)equity of access becomes increasingly apparent, and the smoothly rising ''average'' curve may then take quite different forms.

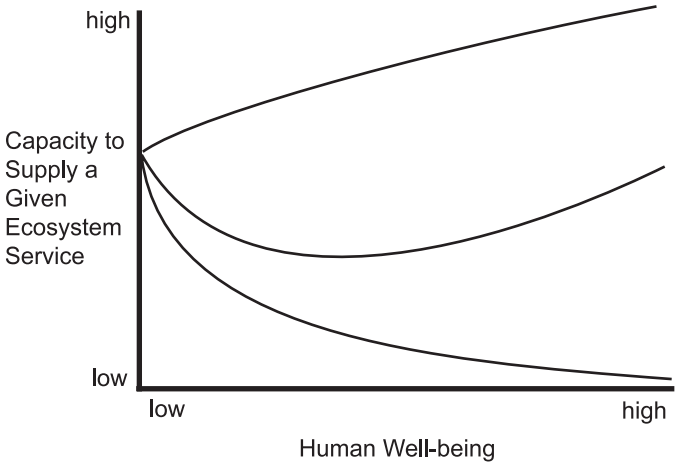

Figure 3.1. Examples of Some of the Possible Shapes of the Relationship between Human Well-being and Ecosystem Service Supply. The hypothesized relationships are for a single ecosystem service, from a particular location, followed over time as the human well-being in that location increases over time. In some cases, such as food provision, the capacity rises to an asymptote. In others, such as services related to biodiversity, it typically falls to an asymptote. Yet in others, such as water quality, it may initially fall, then recover somewhat.

There are plausible cases, such as the global climate regulating service, that may have been in continuous decline over the period of modern increases in well-being (IPCC 2001). The possibility that, for some services, the supply declines initially as well-being rises and then recovers at higher levels of well-being has been much speculated on (Rotmans and Rothman 2003); the resultant shape is sometimes known (albeit controversially) as the ''inverted environmental Kuznets curve.'' An example is riverine water quality in the developed world; the turnaround is usually interpreted as reflecting changing human priorities: once people are above a basic level of needs satisfaction, they have more resources to spare for environmental protection, and place a greater priority on issues such as a safe, clean, and attractive environment. A developing-world example of this pattern may be provided by tree cover in the eastern highlands of Africa. Initial deforestation has led to a gradually increasing use of trees-on-farms in some places, but it was not for environmental protection as much as for labor-sparing, high-yield investment. Figure 3.1 points out that no single form of the ecosystem services/ human well-being relationship holds in all cases.

The agencies responsible for promoting human well-being (for instance, national ministries of development or health) are typically different from those responsible for the protection of ecosystem services (for instance, environment ministries), and this can lead to tensions and non-optimal trade-offs. Even where both functions are within a single agency (for example, fisheries or forest ministries), they must deal with internal conflicts of purpose.

3.7 Issues of Equity and Access

There are important issues of both efficiency and equity of access to ecosystem services. The potential supply of an ecosystem service is not necessarily equal to what is actually used. The reasons for this include changes in demand in relation to the other options available to people, the technology available for the exploitation of ecosystem services, the level of knowledge of users, and restricted access to the service.

South Africa provides many examples of the ecosystem service consequences of inequities institutionalized by the apartheid system and persisting due to entrenched poverty after the formal abandonment of that system. Rural communities in the former tribal ''homelands'' had no rights of permanent residence outside those areas, but had few economic opportunities within them. As a result, they depended on the ecosystem resources that the areas offered, and in many cases overexploited them. Much of this degradation occurred in times of climatic drought or economic hardship (Eastern Cape local assessment, in SAfMA Gariep).

In places where there are no other social safety nets, diminished human well-being tends to increase immediate dependence on ecosystem services, and the resultant additional pressure can damage the capacity of those local ecosystems to deliver services. In Papua New Guinea, a ''destructive poverty syndrome'' was found in the central highlands and the coastal zone—especially on small islands. Destructive poverty is both the driver and the effect of environmental change. In this type of relationship between poverty and the environment, poor people sink further into poverty because their poverty drives them to participate in unsustainable resource management regimes. In contrast, conservative poverty, a form of the poverty–environment relationship in which environmental resources are not damaged or destroyed, was found in the PNG lowland interior and highland fringe.

The capacity to restrict access to a service is fundamental to all successful natural resource management institutions (Berkes 2004). The important question is: who experiences the gains and losses in access under conditions of ecosystem change? And how do the processes of economic and social change lead to displacement of those gains and losses across both space and time? For example, a transnational company may plant crops in a newly cleared area, transforming local ecosystems in ways that render them more productive in food-yield terms, but not necessarily in total ecosystem service terms, and not necessarily in the long term. The shareholders and employees of the company benefit, and presumably the consumers of the food do as well. The losers may include local farmers, harvesters and the people they supply, and those using the other services generated by the original landscape. The future impacts of losses of soil fertility, biodiversity, and ecosystem stability are seldom factored into this calculation, or if they are, they are so heavily time-discounted that they are overwhelmed by the immediate benefits. A useful tool to identify and discuss the benefits for different groups under different land uses is the alternatives to slash-and-burn matrix. (See Chapter 8.) The ASB matrix scores natural forest and various land-use systems that replace it against various criteria reflecting the different objectives of different interest groups (Tropical Forest Margins).

Secure rights to environmental resources (for example, land, water, trees) is an important dimension of well-being that reduces vulnerability. Environmental resources also have ''instrumental value'' (that is, they can be used to obtain something else of value), since they enhance a person's freedom to be and to do. Some assessments (for example, SAfMA Gariep and Coastal BC) addressed inequalities in access to natural resources; the literature highlights particularly the role of gender in determining access (Nunan et al. 2002), but inequality in access also has family, group, regional, and national dimensions and is closely related to power. Differential access to resources may also explain why some people living in environmental-resource-rich areas nevertheless have low human well-being.

Changes in the equity structure of societies can have impacts on ecosystem services. For example, economic liberalization in Viet Nam resulted in the development of a class of entrepreneurs with markedly greater access to capital. The poorer fishermen were unable to enter the capital- and technology-intensive shrimp fishery that developed. Furthermore, the ecological changes precipitated by the expansion of shrimp aquaculture reduced the capacity of the ecosystem to support traditional fish stocks, further exacerbating the inequity (KM–Downstream Mekong).

3.8 The Consequences of Ignoring the Link between Well-being and Ecosystem Condition

The capacity of human communities to form stable societies, to generate formal economies, and to plan for the future is underpinned by environmental stability (predictable fluctuations, such as seasonal changes, are a form of stability), reliable supplies of natural materials, and the adequate functioning of the cleansing and recycling processes of nature. Thus all people and their societies are fundamentally dependent on ecosystem services, although in some contexts the source or importance of particular services is more apparent than in others. In general, the visibility of these linkages tends to vary inversely with the degree of modernization and urbanization. The abundance of arctic mammals as a food source is of direct importance to the nutritional status and survival of the Inuit, and thus they pay close attention to it. On the other hand, the supply of red meat through butchers' shops in a modern city is much less critical to the well-being of metropolitan populations, given the many protein substitution possibilities.

The process of cultural evolution, occurring over centuries but substantially accelerated in the industrial era, has entailed a progressive dissociation of daily needs and activities from the services of the natural world, at least in the perceptions of most people. Subsistence communities have a much more immediate relationship with local ecosystems than do modern urban populations that live at several commercially mediated levels removed from nature. For that reason, both the awareness of human dependency on nature, and the rapidity and spatial immediacy with which ecosystem changes affect human well-being, vary hugely among contemporary human societies, spread across the spectrum from pre-agrarian to post-industrial.

With the global increase in the quantity of goods traded and the distances they travel, the possibility of dissociation of human well-being from local ecosystem conditions increases; the population of high-density Hong Kong, for example, draws on many imported rather than local ecosystem services. Several sub-global assessments highlight the issue of dissociation, including SAfMA Gariep, Portugal, and PNG. Food provisioning in Portugal is a good example; a stagnating or decreasing tendency at the national level of this fundamental service can be compensated for by imports (Portugal). Indeed, daily calorie intake per capita has increased by 4.8% from 1990 to 1997, but national supply of food is also increasingly dependent on imported food products (INE 1999, cited by Portugal).

As the magnitude and reach of human influence increases, so does the degree to which ecological processes that operate over large scales are affected. For instance, processes involving the atmosphere can be transported around the world within days in a west to east direction, and within a year or two in a north to south direction. Affluent populations driving large cars contribute disproportionately to the generation of greenhouse gases, but the environmental consequences both of oil extraction and refining and of global climate change impinge predominantly on groups other than those driving those large cars. While some developed countries may gain crop production potential with projected climate change, in about 40 poor developing countries—with a combined population of 2 billion, of whom 450 million are currently undernourished—production losses due to climate change may greatly increase the number of undernourished (Fischer et al. 2002).

There are also disconnects in terms of temporal sequence. For example, although the onset of critical deficiencies in ecosystem services can appear abrupt, they usually result from a long, unnoticed process of gradual decline. The decline may occur on a broad front, or it may be limited to one particular component or process. For instance, the ''collapse'' of fisheries hits the headlines when emergency measures are put in place to preserve the stocks, but the harvest pressures have usually been unsustainable (and known to be so) for years before that time. Substitution of one stock by another, and the use of progressively more sophisticated fishing techniques, can result in a disconnect between the mass of fish landed, which remains high, and the falling fish populations. Rwanda, with multiple ecosystem limitations, is an example. By the early 1990s, the accumulated pressures on agroecosystems of a large and growing population led to widespread rural shortages of food, clean water, and grazing land. This contributed to the escalation of ethnic tensions and to the ensuing civil conflict. The correspondence between areas of ecosystem service loss and social conflict is suggestive of a link between these two issues. The link could go in either or both directions: conflict creates conditions promoting ecosystem degradation, or environmental resource depletion could be a cause of conflict (SAfMA Regional; Scholes and Biggs 2004).

A decline in the supply of food, water, and materials is the most obvious consequence of adverse ecosystem change for human communities. Less acute or tangible consequences include:

- *the loss of genetic variation as strains of wild and cultivated plants disappear.* The robustness of traditional food supplies has long depended on this genetic diversity;
- *the invisible loss of biochemical diversity, as species go extinct.* Human societies have long depended on the many medicinal and other useful chemicals or materials from nature. It is certain that there are still many such products as yet undiscovered. They cannot contribute to our future well-being if they no longer exist;
- *the loss of recreational, aesthetic, and spiritual benefits* conferred by access to natural settings and the presence of plant and animal species;
- *the loss of environmental stabilization provided by natural vegetation.* This includes surface-water movement (flood control), soil stabilization, the uptake of atmospheric carbon dioxide by plants, and the provision of habitat for many animal species;
- *the loss of cleansing capacity for local water supplies,* provided by water movement through wetlands.
- *the loss of many different processes for the recycling of nutrients* via decomposition, transport, predator-prey transactions, and others.

3.9 Final Remarks

Human well-being has a two-way interaction with ecosystem condition, mediated in the one direction through the services that ecosystems provide to people, and in the other by the largely unintended impacts of human activities on ecosystem functioning. This feedback loop is self-regulating when people live in close and inescapable association with their local environment. If society fails to read the warning signs delivered by a decline in ecosystem services and does not adjust its activities accordingly, it ultimately fails (Diamond 2005). Thus most local communities that have been in one place for long periods of time have developed mechanisms for the protection of ecosystem services. As societies, via modernization and trade, have become less dependent for their well-being on the services provided by their local environments, the coupled human–environment system has become increasingly at risk of overexploitation. In the presence of trade-offs between services, and between ecosystem services and human well-being, overexploitation can lead to unambiguous net loss. People, everywhere and at all times, depend absolutely for their lives and livelihoods on

the adequate functioning of Earth and its component ecosystems, whether local or distant, regardless of their level of awareness of this dependency.

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Chapter 4

The Multiscale Approach

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Main Messages ***63***

4.1 Introduction **63**

4.2 Rationale for a Multiscale Assessment **64**
4.2.1 Definitions
4.2.2 Expected Benefits of a Multiscale Assessment Process

4.3 MA Design and Process **68**
4.3.1 Multiscale Characteristics of the Sub-Global Assessments
4.3.2 Adaptations of the MA Conceptual Framework across Scales
4.3.3 Mechanisms for Linking Assessment Scales
4.3.4 Aligning Assessment and Management Scales

4.4 Assessing Benefits and Costs of Multiscale Assessments **74**
4.4.1 Information Benefits and Costs
4.4.2 Impact Benefits and Costs

4.5 Lessons Learned in Conducting Multiscale Assessments **78**
4.5.1 Conducting Multiscale Assessments
4.5.2 Evolving Scale-related Issues
4.5.3 Multiscale Sub-global Assessments as a Source of Innovation

4.6 How Do Sub-global Assessment Results Inform Global Assessments? **80**

REFERENCES **82**

BOXES

4.1 The Evolving Definition of Scale in the MA Sub-global Assessments

4.2 The Problem of Scale in an Assessment: Western China

4.3 The MA Conceptual Framework across Multiple Scales: SAfMA

4.4 Modeling Intermediate Scales

4.5 Multiscale Assessments: Some Emergent Challenges

4.6 Assessing Biodiversity at Multiple Scales: SAfMA

FIGURES

4.1 Characterization of the Multiscale Nature of the Sub-global Assessments

4.2 Effects of Geographic/Economic Scale on Net Gain, Benefits minus Costs, Arising from Effects of Climate Change on Society and Adaptation's Possible Role in Mitigating Negative Outcomes

4.3 Relationship between Geographical Extent of the Sub-global Assessments Relative to the Time Window Addressed by Each

4.4 Nested, Multiscale Design of Southern Africa and Portugal Assessments

TABLES

4.1 Scalar Aspects of Selected Sub-global Assessments

Main Messages

The MA sub-global assessments were undertaken to meet the information needs of decision-makers at every scale, as well as to test methods for conducting multiscale assessments on ecosystem services and human well-being. This work was conducted in the face of acknowledged and recognized limits in our understanding of multiscale assessment approaches.

A *comprehensive* multiscale assessment is a process that incorporates at least two complete, nested, and interacting assessments, each with a distinct user group, problem definition, and expert group. While the overall MA process was a multiscale assessment as defined here, four categories of sub-global assessments emerged: *comprehensive multiscale assessments; multiscale assessments via analyses; single-scale assessments with explicit multiscale linkages;* and *single-scale assessments with either significant multiscale linkages or with multiscale considerations.* Only two sub-global assessments were conducted as comprehensive multiscale assessments (SAfMA and Portugal). Four other assessments (Argentine Pampas, Coastal BC, Colombia, and Western China) included significant multiscale analyses (for example, detailed case studies of particular sub-regions within the overall assessment), but were not comprehensive multiscale assessments since the case studies did not include their own user groups and problem definitions. All of the MA sub-global assessments examined processes that occur at multiple scales.

The scale at which an assessment is undertaken significantly influences the problem definition and the assessment results. Findings of assessments conducted at different scales differed due to differences in the questions posed and/or the information analyzed. Local communities are influenced by global, regional, and local factors. Assessments conducted at different scales tended to focus on drivers and impacts most relevant at each scale, yielding different but complementary findings. These differences are the basis for some of the benefits of a multiscale assessment process, since each component assessment offers a different perspective on the issues addressed.

Both multiscale assessments and assessments incorporating multiscale analyses face analytical challenges not present in single-scale assessments. Assessments that include analyses undertaken at different scales must grapple with analytical issues not faced in assessments undertaken at single scales, including: (1) the selection and measurement of ecosystem services and components of human well-being, (2) determination of the degree of nestedness; (3) establishment of methods for aggregating or downscaling in order to allow a comparison across scales, and (4) establishment of mechanisms for ensuring information flow across the scales of the assessment.

Multiscale assessments face additional challenges related to the most appropriate model for stakeholder involvement and participation. "Tensions" may emerge from conflicting perceptions created by the presence of separate stakeholder groups from different scales, each with their own needs from the assessment. Whereas a more rigid methodology and protocol may better meet analytical needs for multiscale analyses, a more flexible approach is sometimes necessary to accommodate or adapt to stakeholders from different scales. Thus the two goals of analytical rigor and stakeholder involvement frequently lead to somewhat incompatible multiscale assessment design approaches that must be reconciled.

Policies and institutions designed to enhance the sustainability of the management of ecosystem services at any particular scale often result in winners and losers at finer scales and this, in turn, can lead to the emergence of new institutions and actions at those scales. National policy decisions about market conditions, trade, or transportation typically create winners and losers at local scales. Such tensions can precipitate coalitions and socio-political arrangements among people at more localized levels that aim to overcome skewed power relationships (Coastal BC). These emergent responses and institutions must be accommodated in the design of approaches to manage ecosystem services and to enhance human well-being. Multiscale assessments can be particularly helpful not only by revealing these emergent institutions, but also by highlighting their potential role in managing ecosystem services for human well-being (Caribbean Sea; Sweden KW).

***Comprehensive* multiscale assessments provide a powerful basis for evaluating the robustness and persistence of findings across scales.** An assessment of surface water availability that consistently identifies water scarcity across all scales of analysis means that confidence in the result can be high. In contrast, if a region is identified as water scarce at one scale, but is found to exhibit varying degrees of scarcity and/or abundance at others, assessment teams are compelled to explore the reasons for such discrepancies. Inconsistent findings across scales may stem from data or model inaccuracies, or from local adaptations (for example livelihood strategies at local levels that nullify surface water shortages, such as access to subterranean water sources). All of the above outcomes emerged at different localities in one assessment (SAfMA).

Multiscale assessments are both resource- and time-intensive. These added costs may be justified when the goal is to inform and influence decisions, but a comprehensive multiscale design may not be required if the primary goal is only to formalize knowledge or to test the persistence of patterns. Both the information benefits (that is, how the approach improves the assessment findings) and the impact benefits (that is, how the approach improves the adoption and use of the findings) from the assessments were explored. *Comprehensive* multiscale assessments do provide information benefits: more and better data, ground-truthing of data, and better analysis of the causes of change. Many of these benefits can also be obtained at lower cost by using fewer scales and analyzing intermediate scales (*multiscale analyses*). Comprehensive multiscale designs provide benefits associated with the use and adoption of findings through increased stakeholder ownership and subsequently their capacity to implement and respond to assessment findings (SAfMA).

Multiscale assessments offer insights and results that would otherwise be missed. The variability among sub-global assessments in problem definitions, objectives, scale criteria, and systems of explanation increased at finer scales of assessment (for example, the visibility of social equity issues increased from coarser to finer scales of assessment). The role of biodiversity as a risk avoidance mechanism for local communities is frequently hidden until local assessments are conducted (India Local; Sinai, SAfMA Livelihoods). Processes of common concern emerging at all scales of assessment assumed different meanings and implications at different scales. Examples include *market forces* (which at global scales govern broad allocations of resources such as increases or decreases of forest cover, but at local scales determine livelihood strategies, security, organizational, technical, employment and migration responses); *environmental degradation* (which at global scales involves phenomena like climate change and biodiversity loss, but at local scales becomes increasingly tied to a suite of tradeoffs associated with the provision of ecosystem services upon which livelihoods depend); and *institutional responses* (which range from global agreements and financial commitments to cooperative local resource management and advocacy-aimed capacity-building efforts).

4.1 Introduction

The MA was a multiscale assessment, that is, it consisted of component assessments undertaken at multiple spatial

scales, ranging from individual villages to the globe. Attempts were made to inform the findings at each scale with the findings from assessment components undertaken at other scales. The MA sub-global assessments were carried out not only to meet the needs of decision-makers, but also as a means of testing methods for conducting multiscale assessments related to ecosystem services and human well-being. This work was conducted in the face of acknowledged and recognized limits in our understanding about using multiscale approaches (Wilbanks and Kates 1999; Giampietro 2003; Rotmans and Rothman 2003).

Recognition of the importance of scale in the context of environmental assessments has grown considerably over the past decade (Wilbanks 2003). However, there has been relatively little experience with the use of a multiscale assessment structure in international scientific assessments. Most recent international scientific assessments have been conducted at a single, global scale, such as the Global Biodiversity Assessment, the World Water Development Report, and the Ozone Assessments. Regionalization of the findings from a global assessment perspective was done in the Intergovernmental Panel on Climate Change Third Assessment Report (IPCC 2001). The Global International Waters Assessment, in contrast, is based on nearly 60 sub-global assessments, but again it is not a multiscale assessment since it is based on assessments conducted at a single scale. UNEP's *Global Environment Outlook* process (UNEP 2002) is a global assessment based largely on regional assessments, although it comes somewhat closer to a multiscale structure in that it complements the regional assessments with a global analysis.

This chapter presents the rationale for adopting a multiscale assessment approach, assesses the strengths and weaknesses of the process and methods employed to conduct a multiscale assessment, and evaluates the effectiveness of the approach. Specifically, it examines the extent to which the benefits expected from a multiscale approach were in fact achieved.

4.2 Rationale for a Multiscale Assessment

4.2.1 Definitions

Scale refers to the measurable dimensions of phenomena or observations (MA 2003). It is expressed in physical units, such as meters or years, population size, or quantities moved or exchanged. In observation, scale determines the relative fineness and coarseness of different details, and the selectivity among the patterns that these data may form. Thus scale becomes a filter, or a window of perception through which analysis, observation, knowledge, and information can be considered and/or defined. The details and patterns identified in the assessment of a farm field differ from those apparent in assessing the river basin containing that field. In explanation and action, scale expresses the reach of processes of interest, or the bounds used to confine such processes for analytical or social reasons. For example, a metropolitan region may extend to incorporate its market links, it may be scaled analytically to explain housing patterns, or it may be divided variously among rural and urban jurisdictions for purposes of governance and plans of action.

Hierarchies of scales are viewed primarily as emergent and/or regulating structures, processes, and interactions across a range of spatial and temporal scales (Allen and Starr 1982; O'Neill et al. 1986; Holling 1992; Levin 1992; Berkes 2002; Gunderson and Holling 2002). For example changes to the observable characteristics of cities, towns, and villages are influenced by interactions at coarser scales: the processes of urban resource extraction from rural areas and of rural-to-urban migration. Similarly, a reduction of a species' access to its food supply, whether by natural or human-induced events at a coarser scale, may produce adaptive responses throughout the trophic system of which both predator and prey are part, modifying the extent of influence and characterizing processes of all groupings within the system.

The terms ''scale'' and ''level'' are often confused because both are defined within hierarchical frameworks and can coincide in the same unit. Their meanings are different, however. Scale is a measure of extent, span, size, reach, or detail; it is physically measurable. Level is a characterization of perceived influence; not a physical measure, it is what people accept it to be. A network of cooperating irrigation farmers can contain dozens or thousands of farmers, operating at different scales but on the same level, while state-run irrigation systems at both scales of dozens or thousands of farmers may be perceived to be operating at a ''higher'' level. Species at ''lower'' trophic levels may occupy larger areas for longer times than their predators, which are defined as ''higher'' as a matter of convention. While the two concepts of scale and level may coincide in the same unit (for example, a village), the scale of the village as a unit of land and population is a physical measure. Its level may be ''high'' or ''low'' depending upon, for example, the relative power, wealth, and networks of its occupants, or whether its ecological site is perceived to control or respond to events in the broader landscape. A level of organization is not a scale, but it can have a scale (Allen 1998; O'Neill and King 1998).

The concept of scale can be either applied to the scale of observation of a process or considered a characteristic of the process. (See Box 4.1.) An example of the use of the concept to describe the scale of observation would involve one assessment measuring or observing changes in river hydrology at the scale of a particular catchment area, while another assessment examines changes at the scale of an entire river basin. Many ecological and social processes or phenomena, however, are characterized by a particular extent or duration over which the process or phenomena is expressed; this is referred to as the ''characteristic scale.'' Addressing these characteristic scale phenomena at any other scale can often result in an incomplete (sometimes even mistaken) representation. (See Box 4.2.) For example, cyclical seasonal changes have a characteristic annual time scale that can be misconstrued if viewed only over the span of a few months.

Cross-scale interactions refer to situations where events or phenomena at one scale influence phenomena at another

BOX 4.1

The Evolving Definition of Scale in the MA Sub-global Assessments

Scale was a fundamental MA concept (MA 2003), but the execution of the MA sub-global assessments revealed it to be a far richer and more complex concept than had been anticipated in the initial design. Although initially framed in terms that would achieve consistency between global and sub-global assessments, scale emerged in practice as a dynamic concept that differed, at any one place and moment, depending on whether it was being applied to a problem definition, to an empirical observation, to analysis, or to anticipated action. Moreover, each of these changed in response to the varied contexts of the sub-global assessments as well as the learning that occurred within the assessment teams themselves. What began as a sharply-defined static expectation of scale, emerged as a demonstration of real-world dynamics and ranges of variability. In turn, the sub-global assessments shed light on how even the apparently unambiguous definition of a global scale embraced more possibilities of interpretation than had originally been construed.

scale. The process of forest harvesting, for example, takes place at local scales but can in turn influence regional weather (through changes in evapotranspiration) and global climate (through changes in carbon sequestration). Cross-scale interactions are features of both ecological and socioeconomic systems. For example, regional trade agreements that change commodity prices have impacts on local scale decisions regarding what crops a farmer will plant in a particular year.

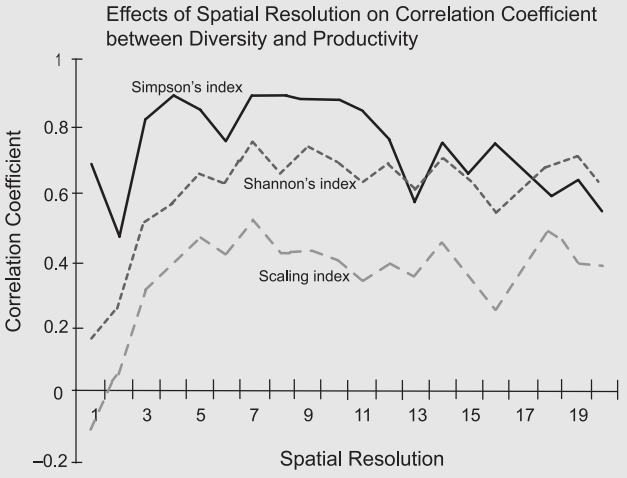
The MA defined an assessment to be a social process that brings the findings of science to bear on the needs of decision-makers. An assessment thus involves close interaction between the experts carrying out the technical work of the assessment and the intended users of the findings of the assessment. The users—that is, the individuals who will act on the findings of the assessment—help to frame the issues that will be assessed. The experts mobilize, synthesize, and assess the data and information bearing on the issues identified by the users (Giampietro 2003). While the overall MA process was a multiscale assessment as defined here, this chapter distinguishes four categories of multiscale assessments among the MA sub-global assessments: *comprehensive multiscale assessments, multiscale assessments via analysis, single-scale assessments with explicit multiscale linkages,* and *single-scale assessments with multiscale considerations*. (See Figure 4.1.)

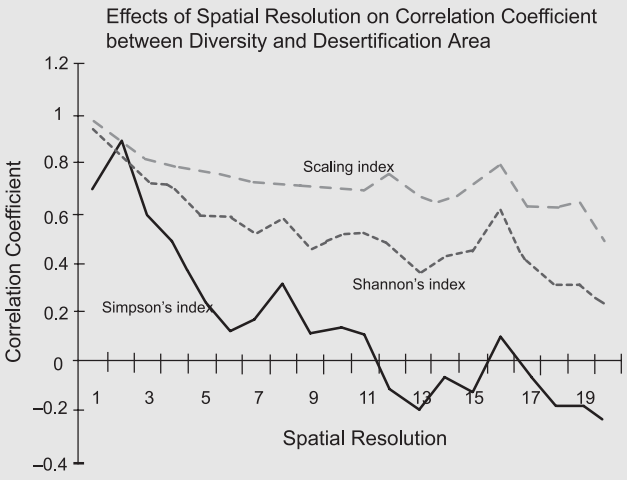
We define a *comprehensive* multiscale assessment process to be one that consists of at least two complete, interacting assessments, one nested within the other, each with its own group of experts, users, and problem definition. Thus the MA global assessment had a set of users involving five international conventions and was undertaken through three global working groups. Nested within the global assessment was, for example, the Southern African Millennium Ecosystem Assessment, which itself consisted of three distinct scales of assessment. At the broadest scale was the SAfMA Regional assessment, which has its own advisory group of users, its own group of experts carrying out the assessment,

BOX 4.2

The Problem of Scale in an Assessment: Western China

The relationship between biodiversity and ecosystem functions such as stability and productivity has a long history of debate. In the Western China sub-global assessment, these relationships were tested in order to highlight their scale dependency (Yue et al. 2004). Results indicate that analyzing the relationship between the ecosystem services provided by biodiversity and its proxy variables is not only complex from the perspective of understanding key processes, but can also present methodological challenges. As the figure below illustrates, unraveling the relationship between these two variables is a difficult task, which is made even more challenging by the fact that the relationship changes with respect to the index chosen to encapsulate biodiversity (there are a large array of biodiversity indices, each of which yields different conclusions when relating these measures to productivity; see CBD 2003 and Magurran 2004), as well as the spatial scale of analysis. From a policy perspective, the figure indicates how focusing on a single observational scale to measure geographically continuous phenomena can lead to incomplete or sometimes simply mistaken conclusions on the nature of ecosystem services.





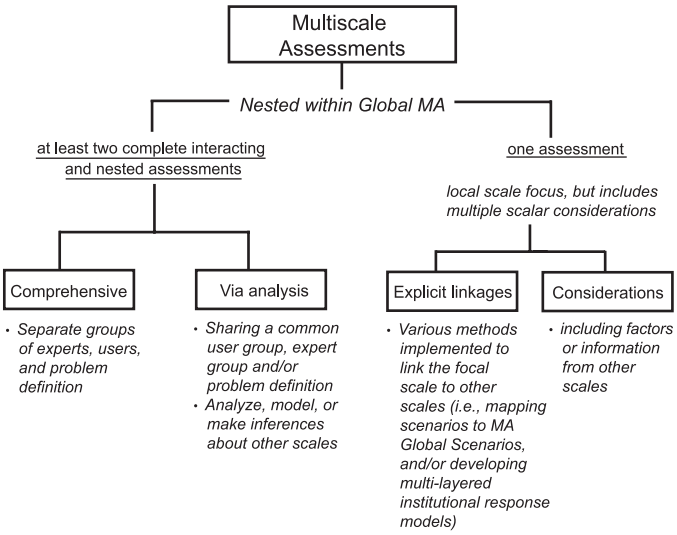

Multiscale Assessments
Nested within Global MA
at least two complete interacting and nested assessments
one assessment
local scale focus, but includes multiple scalar considerations
Comprehensive
Via analysis
Explicit linkages
Considerations
• Separate groups of experts, users, and problem definition
• Sharing a common user group, expert group and/or problem definition
• Analyze, model, or make inferences about other scales
• Various methods implemented to link the focal scale to other scales (i.e., mapping scenarios to MA Global Scenarios, and/or developing multi-layered institutional response models)
• including factors or information from other scales

Figure 4.1. Characterization of the Multiscale Nature of the Sub-global Assessments

and its own reports and products addressing the needs of users from the region of southern Africa. Nested within the regional-scale assessment were the Gariep and Zambezi basin assessments. Nested in turn within SAfMA Gariep were, for example, the Richtersveld and Great Fish River local assessments, which again had their own user groups (local communities), experts (including many community members), and products.

There are two different ways in which an assessment could be construed as a *multiscale assessment via analysis:* by adapting information from other scales or by modeling of intermediate scales. For example, the IPCC is a global assessment carried out for a global body of users as represented by the parties to the U.N. Framework Convention on Climate Change. The IPCC increasingly uses multiscale analyses as a component of its work, incorporating regional analyses of the costs and benefits of climate change and regional analyses of the drivers of climate change such as carbon emissions. We would therefore describe the IPCC assessment as one that incorporates *multiscale analyses,* but not as a *comprehensive* multiscale assessment. While the IPCC reflects on and incorporates inputs from other scales, it does not conduct assessments at different scales. MA sub-global assessments in the multiscale analysis category include: Coastal BC, Western China, Tropical Forest Margins, Argentine Pampas, and Colombia.

A single-scale assessment in the context of the MA is defined as having one complete assessment at a single scale with either *explicit multiscale linkages* or with *multiscale considerations*. *Explicit multiscale linkages* can take the form of mapping the global MA scenarios to local scenarios (see Chapter 11) or of developing multi-layered institutional response models (Sweden KW, Sweden SU, Northern Range, Caribbean Sea, and Tropical Forest Margins). A single-scale assessment with *multiscale considerations* takes into account drivers, stakeholders, processes, or patterns from other scales within the context of the focal scale of analysis (Altai-Sayan, San Pedro de Atacama, India Local, PNG, Laguna Lake Basin, Vilcanota, Downstream Mekong, Bajo Chirripó, Eastern Himalayas, Sinai, and São Paulo).

4.2.2 Expected Benefits of a Multiscale Assessment Process

The idea of conducting the MA as a multiscale assessment was introduced at the first exploratory steering committee meeting for the MA in 1998. This was then refined through a series of meetings during the design phase of the MA, shaped by the growing literature on this topic (Clark 1985; Holling and Meffe 1996; Wilbanks and Kates 1999; Kremen et al. 2000; Kates and Wilbanks 2003; Holling et al. 2002; Giampietro 2003; Rotmans and Rothman 2003).

Considerations of temporal and spatial scales are highly relevant for assessments of processes of social and ecological change (MA 2003). Ecosystem changes may affect human well-being over days or weeks (for example, pest outbreaks that reduce agricultural yields), years, decades (for example, increased sediment loads leading to eutrophication and declining productivity of coastal estuaries), or even longer time frames (for example, global climate dynamics). Similarly, changes at a local (that is, fine) scale may have little impact on some ecosystem services at that scale (as in the local impact of logging a forest patch on water availability) but have major impacts at coarse scales (forest loss in a river basin changing the timing and magnitude of downstream flooding regimes). These points are especially important in cases where ecosystems are shared among different countries, where the transboundary externalization of environmental problems may be frequent.

Scale considerations are important for the MA with respect to the causes and impacts of ecosystem change. For example, factors affecting ecosystems include drivers with global impacts such as climate change and invasive species introductions, regional impacts such as regional trade or agricultural policies, and local impacts such as land use practices and the construction of irrigation systems. In addition, changes to ecosystems can have global consequences such as the contribution of deforestation to climate change; regional consequences such as the impact of nutrient loading in agricultural ecosystems on coastal fisheries production; and local consequences, such as the impact of overharvesting or land degradation on local food security.

Scale considerations are also important in the assessment of response options. Policy, institutional, technological, and behavioral responses to ecosystem-related issues can involve global actions such as international financial support for biodiversity conservation (Global Environmental Facility and Conservation International); regional action such as regional agreements to promote wetlands conservation for migratory bird protection; and local responses, such as a decision by a farmer to alter land management practices to conserve topsoil. Indeed, unlike some global environmental issues such as climate change, a large share of the decisions affecting ecosystems take place at sub-global, including local, scales. The decisions that will ultimately matter most will be those taken by national governments, private companies, individual land owners, and local land managers.

By the time the technical work of the MA global and sub-global assessments began in 2001, the rationale for the multiscale structure of the MA involved two basic expectations. First, it was expected that the use of a multiscale structure would provide *information benefits* by improving the assessment findings, and their applicability, at all scales. Second, it was expected that the use of a multiscale structure would also provide *impact benefits* for the assessment, by improving the relevance, utility, ownership and legitimacy of the assessment with decision-makers.

4.2.2.1 Information Benefits

The information benefits that would be expected from a multiscale assessment (in contrast to a single-scale assessment) would arise for the following reasons:

- *Better problem definition* (Kates and Wilbanks 2003). A single-scale assessment tends to focus too narrowly on the issues, theories, and information most relevant to that scale. Perspectives gained from other scales would contribute to a fuller understanding of the issues.
- *Improved analysis of scale-dependent processes.* As noted, many ecological and social processes exhibit a characteristic scale. If a process is observed at a scale significantly smaller or larger than its characteristic scale, there would be a likelihood of drawing the wrong conclusions (MA 2003). For example, a short-term observation of a trend in temperature or precipitation (over a week or month) cannot be used to infer long-term changes in climate. Similarly, global aggregate information tends to mask the basic patterns of ''winners and losers'' that often are responsible for the ecosystem changes occurring at the local level and that largely define the potential response options available to communities. (See Chapter 11.) Figure 4.2 illustrates how the net gains from climate change, and the winners and losers therefrom, vary by spatial scale.
- *Improved analysis of cross-scale effects.* Understanding cross-scale effects is often key to understanding processes of ecological and social change. For example, the direct cause of a change in an ecosystem is often intrinsically localized (a farmer cutting a patch of forest), while the indirect drivers of that change (for example, a subsidy to farmers for forest clearing) may operate at a regional or national scale. Similarly, some ecosystem services are *delivered* at finer scales but *produced* through processes operating at coarser scales. For example, food is produced at a local, short-term scale, but this production is also governed by regional processes such as climate and watershed dynamics (for example, availability or quality) and by long-term processes such as soil formation (for example, turnover of organic material) and maintenance (for example, cropping practices).
- *Better understanding of causality.* The relationships among environmental, social, and economic processes are often too complex to fully understand when viewed at any single scale. Studies at additional scales are often needed to fully understand the implications of changes at any given scale. For example, a farmer's choice of which crop to plant in any given period is not only determined by local climate and soil characteristics, but also strongly influenced by the prevailing market prices for specific crops, which are a function of other scales of organization. At the same time, market prices are themselves a function of aggregate demand and supply.
- *Improved accuracy and reliability of findings.* Sub-global assessment activities can help to ground-truth the global findings. Aggregated global syntheses necessarily leave out local details. However, when those aggregated conclusions or indicators clearly diverge from the on-the-ground reality at a specific locality, they can be very misleading. This situation can arise when the problem has been inadequately defined, or when ''best available'' data used for global syntheses is in fact not sufficiently reliable to enable local interpretation.

Scale-dependent Distribution of Impacts of Climate Change (adapted from Environment Canada)

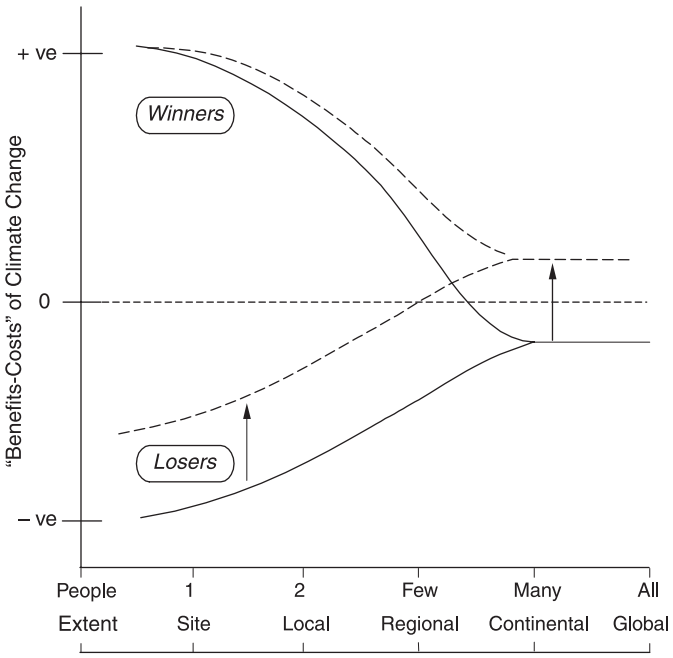


Figure 4.2. Effects of Geographic/Economic Scale on Net Gain, Benefits minus Costs, Arising from Effects of Climate Change on Society and Adaptation's Possible Role in Mitigating Negative Outcomes (Wilbanks 2003)

4.2.2.2 Impact Benefits

The information benefits would presumably also enhance the ultimate use and impact of an assessment, since the assessment findings would be more credible and reliable. However, multiscale assessments were also expected to provide other benefits in addition to those related specifically to the scientific findings; these additional benefits were expected to be obtained from multiscale assessments by virtue of the presence of separate user groups in a *comprehensive* assessment process conducted at different scales. Specifically, the impact of each component assessment was expected to be enhanced through the multiscale structure for the following reasons:

- *Improved relevance of the problem definition and assessment findings for users and decision-makers*. The primary purpose of each MA sub-global assessment was to meet the needs of the decision-makers or users at the location and scale where each component assessment was undertaken. Differences in the framing of the issues to be addressed in an assessment can provide benefits in terms of the analysis (as noted above), but can also make an assessment far more relevant to users at different scales. Clearly, an assessment focused on (and dictated by) the specific needs of the users at that scale will be more relevant than an assessment in which users have little input.
- *Improved scenarios*. An important element of the MA process was to develop and explore scenarios to help reveal the impact of changes in ecosystem services on people. The key uncertainties that a local community may identify as differentiating reasonable future pathways of development may often be different from those identified by users at regional or global scales. At each scale, the scenarios used could thus incorporate the effects and considerations from coarser and finer scales.
- *Increased ownership by the intended users*. Even if an assessment is technically credible and focused on relevant issues, the intended users of an assessment may not use the findings if they do not feel a level of ownership in the process or if they do not view it as politically legitimate (Clark and Dickson 1999). A multiscale structure could increase the legitimacy of each of the component assessments. For example, the legitimacy of the global assessment could be enhanced for governments by virtue of the presence of sub-global assessments in individual countries. In particular, any country undertaking one of the sub-global assessments would likely have greater ownership in the global findings. Similarly, the legitimacy of sub-global assessments for the users of those assessments could be enhanced by virtue of its participation in a globally authorized assessment mechanism.
- *More balanced assessment results*. The choice of scale for an assessment is not politically neutral, because that selection may intentionally or unintentionally privilege certain groups (MA 2003). The adoption of a particular scale of assessment limits the types of problems that can be addressed, the modes of explanation, and the generalizations that are likely to be used in analysis. For example, users of a global assessment of ecosystem services would be interested in some issues such as carbon sequestration that may be of relatively little interest to users of a local assessment. In contrast, the users of a local assessment might be more interested in questions related to sanitation or local commodity prices that would not necessarily be the focus of a global assessment. Similarly, a global assessment is likely to implicitly devalue local knowledge (and the interests and concerns of the holders of that knowledge) since it is not in a form that can be readily aggregated to provide useful global information, while a local assessment would reinforce the importance of local knowledge and the perspectives of holders of that knowledge. Incorporating multiple assessments in a single process balances the various approaches and helps mitigate potential structural biases associated with the choice of scales.
- *Increased capacity-building*. The MA was created with the dual goals of meeting decision-makers' needs and building institutional and individual capacity to undertake integrated assessments and act on their findings. While there would be opportunities to meet this capacity-building goal at the global scale, for example through the involvement of new experts in the global assessment process, the opportunities were expected to be much greater at sub-global scales, where more individuals could receive training in the assessment approach and more institutions could become involved in the process.

The MA experiment with a multiscale approach is ongoing, since many MA sub-global assessments were not yet completed as this volume was written. Even so, the experience gained thus far provides important lessons regarding the process of designing and carrying out a multiscale assessment. There is already sufficient evidence available to allow a preliminary assessment of which expected benefits were actually achieved, and at what costs.

4.3 MA Design and Process

4.3.1 Multiscale Characteristics of the Sub-global Assessments

The original MA design called for a relatively top-down approach to the establishment of four clusters of sub-global, multiscale assessments, three of which were to be located in developing countries/regions and one in an industrial country/region. Each of these multiscale clusters was to involve at least two nested assessments from the following broadly defined categories: one regional assessment, one or more national (or basin-level) assessments, and one or more local assessments. These clusters of assessments were to be complemented by one ''outlier assessment'' (to address important ecosystems not included in the four clusters) and one ''cross-cutting assessment'' to examine similar ecosystems at similar scales in different regions.

Only one such cluster, the Southern African Millennium Ecosystem Assessment, was actually established following this top-down approach to developing nested clusters of assessments. This approach proved to be cumbersome, and by early 2002, the MA Sub-Global Working Group proposed a bottom-up approach for establishing other sub-global assessments. (See Chapter 6 for a detailed discussion.) Using this approach, small seed grants were provided to facilitate the establishment of further sub-global assessments.

Under both the top-down and bottom-up approaches, the choice of scales for a particular assessment was determined by the proponents of each assessment. Through both selection criteria and funding criteria, however, the MA did attempt to encourage the establishment of multiscale assessments. Specifically, the MA selection criteria for sub-global assessments stated that nesting was to be one of two key features of MA sub-global assessments (''*a goal of the selection process will be that most of the assessments included in the MA will involve at least three scales of 'nesting'—e.g., a local assess-*

ment nested within a regional assessment nested within the global assessment''). The criteria also indicated that assessments with more than two scales of nesting would be given higher priority for funding. The MA selection criteria further stated that ''*all MA sub-global assessments must actively engage with assessments undertaken at larger (i.e. coarse) and smaller (i.e. fine) scales*'' (MA 2002).

The scales of the MA sub-global assessments (or component assessments of multiscale sub-global assessments) were generally described in geographical terms (for example, the Altai-Sayan Ecoregion, the SAfMA Gorongosa-Marromeu transect, small islands of PNG) or sociopolitical terms (for example, Indian local villages and Portugal). Scale in this context refers to the perceived influence of the dominant issues or questions being addressed by each assessment. Thus the Portugal assessment focused on changes taking place in ecosystems in Portugal, and the effect that those changes have on the people of Portugal. But in order to assess the state of knowledge bearing on those questions, the Portugal assessment did not restrict its analysis to processes taking place at the scale of the country. The assessment examined global processes (for example, the potential impacts of global climate change or changes in trade regimes), regional processes (for example, policies that the European Union might establish that would affect ecosystems in Portugal), national processes (for example, changes in the fishing industry), and local processes (abandonment of agricultural fields in Sistelo, a community in northern Portugal). Similarly, each sub-global assessment examined processes across a range of time scales, selecting those most relevant to the issues being addressed.

The scale of each sub-global assessment thus described the lens that was used to focus the assessment and, in the user-driven assessment process, was heavily influenced by the questions that the users sought to have the assessment address. The scale of an assessment, however, did not restrict the processes or phenomena that were examined—most assessments examined processes at coarser and finer scales.

In general, there was a positive correlation between the geographical extent of an assessment and the time window that it addressed. (See Figure 4.3.) This pattern is consistent with the expectation that processes with relatively coarse spatial extents will also have relatively long temporal windows. However, exceptions do exist: for example, broad climate processes, such as *El Niño,* may act over relatively short time horizons (years), while relatively localized processes such as local nutrient cycles may take place over decadal time spans.

All of the MA sub-global assessments were, by definition, part of a multiscale assessment, since each was nested in the global assessment and interacted with the MA global working groups. However, the sub-global assessments themselves differed significantly in the extent to which each was conducted as a multiscale assessment. Table 4.1 summarizes the categories of scalar considerations of selected sub-global assessments. Most (14 out of 23) operated at a single spatial scale, while considering relevant factors operating at various scales or information from other scales. As all of these assessments were nested within the global assessment, each had the potential to be involved in at least a two-scale assessment process. Only two MA sub-global assessments, Portugal and SAfMA, were *comprehensive* multiscale assessments as defined above. Two other assessments, Western China and Coastal BC, included significant multiscale analysis within their processes, even though they did not completely fit the definition of a *comprehensive* multiscale assessment. Although the nesting of the sub-global assessments themselves was therefore far less than originally intended, this set of assessments still provides a significant basis for examining the benefits of a multiscale structure by virtue of the fact that each was nested within the global assessment.

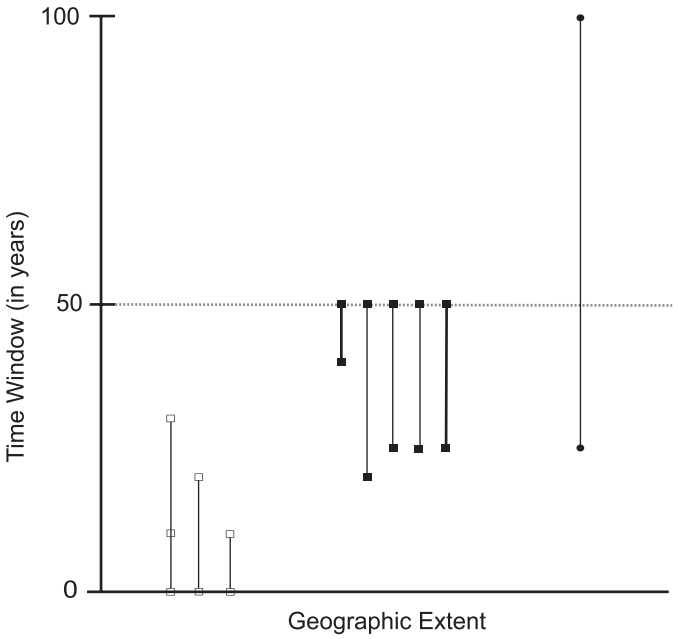


Figure 4.3. Relationship between Geographical Extent of the Sub-global Assessments Relative to the Time Window Addressed by Each. Lines represent the time window (in years) used to analyze the status of ecosystem services. Note that an increase in geographical extent (scale) of consideration appears to be positively correlated with the time window considered in the assessment. This pattern is consistent with the expectation that processes with relatively large spatial extents (which will tend to be the focus of assessments at coarser scales) will also have relatively longer temporal windows.

The assessments that incorporated *comprehensive* nested assessments (SAfMA and Portugal) or nested case studies (Argentine Pampas, Coastal BC, Western China) were structured in somewhat different ways. (See Figure 4.4.) SAfMA involved separate assessments undertaken at three scales (multi-country region, river basin, and local community), and every finer-scale assessment was nested within the next coarser-scale assessment. Western China, with two explicit scales of analysis, followed a similar fully-nested design (with each of the five smaller scale sub-regions nested within a larger regional scale assessment) but involved only two scales (regional and sub-regional). Portugal involved

Table 4.1. Scalar Aspects of Selected Sub-global Assessments. The categories presented here on the nature of multiscale considerations across the sub-global assessments are distinguished by the relative emphasis given to more than one scale of analysis. (See Figure 4.1.) An assessment is characterized as a *comprehensive multiscale assessment* if each of its component assessments has a primary goal of meeting user needs at the scale where it is conducted, has an identifiable user group (typically represented by an advisory group or board at that scale), and is producing separate products specifically addressing the needs of the user group at each scale. An assessment is considered to be an *assessment that incorporates multiple scales via analysis* if it has significant analytical components focused on different scales (for example, a set of case study sites at different scales). *Assessments at a single scale* also include factors or information from other scales.

			Assessment at a Single Scale with:			
Assessment	**Comprehensive Multiscale Assessment**	**Assessment that Incorporates Multiple Scales via Analysis**	**Explicit Linkages**	**Multiscale Considerations**	**Spatial Scale**	**Temporal Scale**
Altai-Sayan				yes (transboundary ecoregion in Altai and Sayan mountain ranges in Russia, Mongolia, Kazakhstan, and China)	local basin national ecoregion	unspecified
San Pedro de Atacama				yes (Salar de Atacama salt marsh in the northern desert of Chile)	local	20 years
Caribbean Sea			yes (regional assessment of marine and island systems in the Caribbean)		regional	25–50 years
Coastal BC		yes (northern and central coastal region of British Columbia)			site subregion region	unspecified
Tropical Forest Margins		yes (a large-scale tropical forest analysis with regional and local case studies at the basin and household levels)	yes (cross-cutting assessment of sites in the forest margins of the humid tropics in South America, Africa, and Southeast Asia)		local basin regional	25–50 years
India Local				yes (local villages in Karnataka and Maharashtra states in India	local	unspecified
Norway				yes (pilot assessment in the Glomma basin in southern Norway)	basin	unspecified
PNG				yes (coastal, small island, and coral reef systems nationwide, with a focus in Milne Bay Province)	local	10 years
Laguna Lake Basin				yes (Laguna Lake basin near Metro Manila)	local	10 years for most ecosystem services, 30 years for fisheries

Portugal	yes; national assessment with case studies at the basin level (Mondego Basin and Mira Basin) and at the local level (Sistelo, Quinta da França, Herdade de Ribeiro Abaixo, and Castro Verde)				local basin national	50 years
SAfMA	Yes; regional assessment of southern Africa (SAfMA Regional); Gariep basin (SAfMA Gariep); Zambezi basin (SAfMA Zambezi); local assessments in Gariep basin (SAfMA Livelihoods), and Gorongosa-Marromeu (SAfMA G-M)				local basin regional	25–50 years
Sweden KW				yes (local assessment: Kristianstad Wetlands)	local	unspecified
Sweden SU				yes (local assessment: Stockholm Urban)	local	unspecified
Northern Range			yes (Northern Range)		sub-national national	25 years
Vilcanota				yes (Vilcanota region of Peru)	local	unspecified
Downstream Mekong				yes (downstream Mekong wetlands)	local	unspecified
Western China		yes, entire western region of China, with six typical sites			local basin regional	20–50 years
Argentine Pampas		yes (farms scale, ecoregions, pampas region, basin)			local ecoregion basin production zone	1–40 years
Bajo Chirripó				yes (local assessment)	local	unspecified
Colombia		yes; district, department, meta-region (main coffee producing)			local sub-region region production zone	Unspecified
Eastern Himalayas				yes (local assessment)	local	unspecified
Sinai				yes (local assessment)	local	unspecified
São Paulo				yes (three reservoirs)	local	10 years

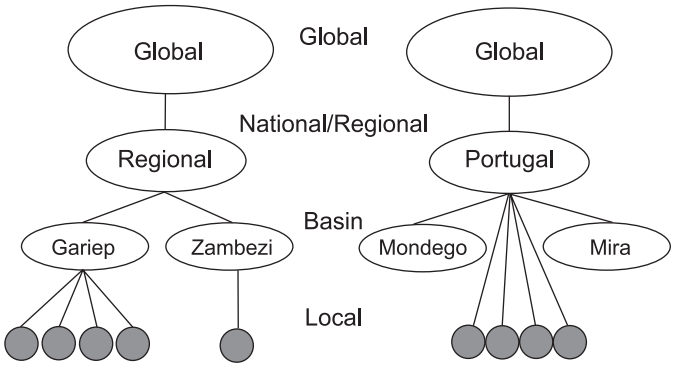


Figure 4.4. Nested, Multiscale Design of Southern Africa and Portugal Assessments. The Portuguese assessment was undertaken at three scales: national, basin, and local. There were two basin assessments and four local assessments. The local case studies were not within the basins studied, and covered different reporting units (systems) of the national assessment. These were a very small rural community (mountain system), two farms (cultivated system) and a biological research station (montado system). Within the Southern Africa assessment, five local-scale assessments, each covering the area of a community or local authority, were nested within two basin-scale assessments, which in turn lay within an assessment of the greater SADC region. All contributed to the global-scale assessment. (Adapted from Box 9.6)

three explicit scales of analysis (national, basin, and local), with nesting between the national scale and the basin scale, and between the national scale and the local scale, but not between the basin and local scales themselves. Western China is not considered a *comprehensive* multiscale assessment, as the smaller scale analyses formed case studies for the larger-scale analyses rather than full assessments in themselves. Similarly, Argentine Pampas incorporated various scales of analyses and envisaged a multiparty stakeholder approach. Importantly, these differences in the design strategies employed also reflected how the ecological and social dimensions of the various sub-global assessments were addressed.

The *comprehensive* multiscale assessment design, as utilized by Portugal and SAfMA, was by far the most resource-intensive assessment approach. This is because it required independent data sets, as well as independent groups of experts and stakeholders. SAfMA employed global data sets for the regional assessment, national statistics and data sets at the basin level, and local statistics and information derived directly from local communities for the local assessments. The comprehensive multiscale assessment designs provided significant benefits in terms of the level of stakeholder engagement and ownership of the findings at different scales, and it provided a powerful basis for evaluating the consistency of findings across multiple scales.

One consequence of the diversity in nesting designs used by the various sub-global assessments was that the assessments differed with respect to the intermediate layers of assessments between a given component assessment and the global assessment. At one end of the spectrum, the single-scale sub-global assessments had no intermediate layers between their assessment scales and the scale of the global assessment. At the other end of the spectrum, the local assessments in Portugal and the community assessments in southern Africa were linked to the national or regional assessments, with an intermediate link within southern Africa between the two at the basin level. These were, in turn, linked to the global assessment. This difference allowed exploration of the costs and benefits of the presence of these intermediate layers. For example, does the presence of multiple intermediate layers result in a heavy filtering of the information and perspectives from the local assessments such that they have less influence on the global findings? Or, alternatively, does the presence of multiple intervening layers of assessments provide a mechanism to better amplify the local findings for use in the global assessment?

The sub-global assessments also adopted different approaches to obtain some of the benefits related to the involvement of stakeholders at different scales, even when they did not use a *comprehensive* multiscale assessment structure. The Swedish assessments (Sweden KW and Sweden SU), which were local, single-scale assessments, involved stakeholders from local, regional, and national scales, and from multinational organizations, all of them representing particular constituencies and bringing additional information, insights, and needs from different scales to the assessment process. This arrangement had several advantages, in that it led to better problem identification and assisted with the analysis of scale-dependent processes and cross-scale interactions. However, the ownership of any particular group of stakeholders in the process will likely be lower, and the responsiveness of the assessment to the specific needs of stakeholders at any particular scale could also diminish as a result of this multiscale stakeholder strategy.

4.3.2 Adaptations of the MA Conceptual Framework across Scales

Although the sub-global assessments participated in the formulation of the MA conceptual framework (MA 2003), the application of the conceptual framework proved to be challenging for many sub-global assessments. (See Chapter 6.) Some of these challenges in applying the conceptual framework appeared to relate to scale. In general, the MA conceptual framework tended to be more readily applied at coarser scales than finer scales, even within individual multiscale assessments, such as the SAfMA. (See Box 4.3.) A common concern expressed by the sub-global assessments related to the difficulty of capturing the multidimensional aspects of interactions at the local scale in the MA conceptual framework. (See Chapters 6 and 11.) Many sub-global teams argued that the conceptual framework implied a relatively static and deterministic relationship among drivers, ecosystem services, and human well-being, when it was strictly applied at a local scale. These assessments (mainly, SAfMA Livelihoods, Vilcanota, and Bajo Chirripó) spent a significant portion of their time reshaping the MA conceptual framework to capture the multidimensional perspectives of the local level. (See Chapters 5 and 11.)

Capturing these multidimensional perspectives required not just considerable investments of time, but also innovative

BOX 4.3

The MA Conceptual Framework across Multiple Scales: SAfMA

During the initial planning meeting, a common design framework for SAfMA was established. The decision was to have a *regional* assessment, *basin-scale* assessments (as water was considered an important driver in the region), and *local* community assessments. The scale of the local assessments was interpreted in a loose fashion to accommodate the focal issues to be explored in those assessments. Thus some local assessments turned out to be very fine-scale (for example, Richtersveld and Great Fish River), whereas others were more expansive in area covered (Gorongosa-Marromeu and Gauteng). Each of these assessments adapted the MA conceptual framework in a variety of ways.

In the regional assessment, the conceptual framework formed the basis for the way in which different ecosystem services and response options were assessed. For each service, the impact on human well-being was examined, as well as the major factors affecting the service and possible responses that could be adopted to ensure its continued provision. The conceptual framework was also used as the basis for synthesizing existing scenarios work, and developing the two regional-scale scenarios for southern Africa.

At the local level, the MA conceptual framework was useful but insufficient to tackle the complex relationship between ecosystem services and human well-being. (See also Chapter 11.) These assessments found that local people constantly adjust their livelihood strategies to cope with long-term and short-term changes in the environment. Furthermore, key resources such as water, fuelwood, food, and livestock varied in response to rainfall and trends in demand. This led to a dynamic interplay between ecosystems and humans, which required additional conceptual frameworks to be "superimposed" on the MA framework. The first, the adaptive renewal model (Gunderson and Holling 2002) enabled the conceptualization of ecosystems and humans as complex adaptive systems that undergo cycles of collapse and reorganization. The second, the sustainable livelihoods framework (Carney 1998), was useful to conceptualize livelihood strategies as long-term responses to reduce people's vulnerability rather than as short-term reactions to change. The three frameworks were used in a complementary manner, and their combined application helped the assessment team to overcome most of the shortcomings of the MA conceptual framework.

participatory methods (including, for instance, community theater techniques) to facilitate communication between assessment teams and communities with primarily oral histories. At the regional or global scale, the MA framework was better able (and thus easily adopted) to capture the dynamics of ecosystem change and impacts on human well-being. At these coarser scales, the conceptual framework also facilitated the structuring of the assessment work (SAfMA Gariep; Bohensky et al. 2004), in particular the work conducted on scenarios at the regional-scale (SAfMA Regional; Biggs et al. 2004). While the adaptation of the conceptual framework to better meet user needs at different scales increased the utility of each assessment at the scale where it was conducted, it also increased the challenge of synthesizing information across scales in the multiscale structure.

4.3.3 Mechanisms for Linking Assessment Scales

During the design phase of a multiscale assessment, considerable attention must be given to defining the mechanism and process for integrating across the different scales of the assessment. The experiences of the global MA process and of SAfMA showed that integration was difficult to achieve if such mechanisms were not already established before the assessments commenced. The lesson learned here is that, from the outset of an assessment, the methods and approaches to be used to achieve integration need to be defined as clearly as possible.

Rather than relying on statistical methods to scale results up or down across the assessment scales, SAfMA decided to use a common set of ecosystem services as the basis for comparison across scales—food, water, and biodiversity. The assessment team also decided upfront to use a scale-invariant approach that focused on assessing the differences between supply and demand for each service. In the case of water, the common variable employed was cubic meters per person per day, assessed against the U.N.-identified thresholds for water scarcity and water stress. In the case of food, kilocalories per person were used for carbohydrates while grams of protein per person were used for assessing protein nutrition compared with the World Health Organization thresholds for adequate nutrition. For biodiversity, the common approach was the average change in the population size of all species of plants and vertebrates in the particular analytical unit considered, relative to the populations in large protected areas in the same ecosystem type. This use of a common approach significantly facilitated comparisons across component assessments and subsequent integration across scales using the principle of spatial congruence. Individual component assessments nonetheless retained significant flexibility to incorporate additional variables, drivers, and stakeholder group requirements.

As part of the same approach, SAfMA used independent datasets for each of the scales analyzed. The regional assessment made use of regional and global data sets, the basin-level assessments used only national statistics and data sets, and the local assessments used only locally derived data. The principle was to avoid using the same data at different scales, as it could potentially confound the emergence of scale-specific patterns and processes. Similarly, the use of different data from various scales in a multiscale analysis can add significantly more depth and richness than an assessment conducted at only one scale.

Other MA sub-global assessments used a number of different approaches and methods to explore issues related to spatial and temporal scale relevant to their assessments and to overcome challenges related to the multiscale design. Box 4.4 describes some of these other approaches.

The steps taken to enable integration of findings with the global assessment were quite diverse. Unlike the approach taken within the Southern Africa assessment itself, the MA Sub-global Working Group did not require that common variables (or services) be measured across all of the sub-global assessments. The concern was to allow the sub-global assessments to focus on addressing the needs of users

BOX 4.4
Modeling Intermediate Scales

The Western China assessment used coarse-scale and very fine-scale information to model an intermediate scale. This can be a very cost-effective method, especially if the intermediate scale is data poor and stretches over vast areas or, as in Western China, there is simply no decision-making or data assimilation incentive for intermediate scales. This approach does, however, seem to compromise the potential benefits envisioned from the benefits of a multiscale approach, especially with regard to independent data sets.

Many assessments employed innovative approaches to capture the temporal trends in ecosystem services. Western China, for example, used the archives available from weather stations to assess the temporal changes of terrestrial ecosystems. Similar methods, utilizing satellite image archives and other emergent spatial technologies, to address temporal changes in ecosystem services were employed by other sub-global assessments (Argentine Pampas, Portugal, SAfMA, as well as Western China). These approaches differ from those that generated entirely new data sets, which can be used as important baseline information for future assessment efforts (India Local).

at the scale at which each assessment was conducted, rather than to be constrained by ''global'' issues and variables imposed by the Working Group. This provided sufficient flexibility to the sub-global assessments, but also made it difficult to compare some global MA findings with the sub-global assessment findings. The following primary mechanisms were established at the outset to integrate the global and sub-global findings:

- the MA Assessment Panel (the chairs of all the Working Groups were members of the Panel and took decisions regarding substantive aspects of the overall MA);
- overlap of individuals in the global and sub-global assessments;
- posting of interim sub-global assessment information on the MA Intranet for the use of global authors; and
- the review process (involvement of global authors in reviewing sub-global assessments, and vice versa).

As the assessment drafts were being prepared, it became apparent that these types of linkages were insufficient. There was relatively little reflection of the sub-global findings in the global assessment, and vice versa. The MA then established a ''global–sub-global linkage team,'' which reviewed the draft global and sub-global materials to identify possibilities for the inclusion of more sub-global information in the global reports, and vice versa. This mechanism did enhance both global and sub-global products of the MA. Much of the challenge in linking scales related to the parallel process of undertaking the component assessments in the MA. If the sub-global assessments had been completed prior to the global assessment, for example, the findings of the sub-global assessments could have been more easily incorporated in the global process but they, in turn, would have not have benefited from the findings of the global process. When viewed as a one-off assessment, this is a particularly problematic situation. However, if an assessment like the MA is repeated in the future, then there would be ample opportunity for future global and sub-global assessments to benefit from the collective MA experience.

4.3.4 Aligning Assessment and Management Scales

Given the multiple scales over which ecological processes take place, and the multiple scales over which ecosystem management decisions are made, there can never be a single ''correct'' scale at which to conduct an assessment. In general, the problem of a mismatch between assessment scale and management scale is addressed by focusing the assessment on an appropriate scale for the particular concerns and issues identified by decision-makers. Even following this approach, the availability of information or the characteristics of the ecological and social processes may mean that information cannot be provided to the decision-makers at the scale at which it will be most relevant. Within the MA sub-global assessments, some assessments selected the most appropriate ecological units for analysis, and then subsequently matched this information to the relevant sociopolitical units as closely as possible (for example, SAfMA Gariep); others chose the most appropriate sociopolitical units with secondary consideration of ecological units (for example, Western China); and others aimed to do both, depending on the context (for example, Portugal and Coastal BC). The trade-off involved is straightforward: the first approach provided more complete and accurate, but less sociopolitically relevant information, while the latter approaches increased relevance to decision-makers but at a cost to accuracy.

Some sub-global assessments also selected user groups that were not traditional decision-making bodies. The approach most often employed was to use multistakeholder groups (which included representatives from different types of decision-making bodies, some of which may function at different scales) to align management and decision-making structures with the pre-selected ecological scales (Coastal BC, Sweden KW, and Sweden SU). The advantage of this approach is that novel decision-making structures may evolve, but the downside is that ownership of issues is either not clearly defined or not readily assumed among the diverse stakeholders. In addition, specific analytical approaches were selected for certain areas in order to capture the required balance between user group needs and ecological features of the system. The use of material flow accounting methods in the highly urbanized Gauteng urban assessment (SAfMA Gariep), where management scales are localized but ecological resources are external to the assessment scale (that is, are imported), was one way in which management and ecological scales were matched. In addition, both SAfMA and Portugal matched designs with levels of available or collected data. SAfMA Gariep, for instance, assembled a user group that reflected a combination of national, provincial, and local authority stakeholders involved in the management of the Gariep Basin.

4.4 Assessing Benefits and Costs of Multiscale Assessments

This section examines the information and impact benefits and costs of the multiscale approach.

4.4.1 Information Benefits and Costs

The information benefits highlighted by the sub-global assessment teams resulted primarily from increased communication and information flow among assessment teams operating at various scales of analysis; particularly beneficial was the improved information available from the local assessment processes. These benefits appear to be related to an increased sensitivity to local-scale perspectives, which influenced the underlying approaches to regional and basin-scale assessment activities. The specific benefits include:

- *Increased attention to social perspectives*. In the southern Africa assessment, greater consideration was give to social issues than originally anticipated. Initially, the pilot assessment derived patterns and processes responsible for food shortages based on a biophysical approach to the analysis of food, using variables such as food distribution as a function of infrastructure, production capacities of the environment, and demand as a function of population size alone. By incorporating local-scale perspectives, the full assessment of food and local livelihoods issues permitted the incorporation of local-scale problems of access to food, synthesizing data from a meta-analysis of 50 on-the-ground case studies of food insecurity at the local level in southern Africa (SAfMA). Together, these perspectives provided more detailed and locally relevant data on food security than initially envisioned. (See Chapter 11.)
- *Framing of results and conclusions*. The multiscale approach resulted in increased attention to the likelihood that regional findings may not adequately reflect sub-regional differences due to the use of analytical methods that tend to neglect local heterogeneity. For example, SAfMA originally intended to present fuelwood availability in terms of production and demand models in order to identify areas of excess and deficiency. Instead the data were discussed in a more nuanced way: areas of fuelwood excess when examined from a regional scale may well contain local areas with severe shortages; similarly areas of overall shortage may contain locations with sufficient fuelwood supplies.
- *Increased awareness of stakeholder needs*. The multiscale approach helped to focus findings on the needs of decision-makers at the scale of each component assessment. A regional-scale report will not necessarily speak to local-scale stakeholders. The perspectives and issues addressed are those of relevance and importance to regional or national decision-makers; other perspectives and issues may well have to be adopted and addressed to be meaningful to local-scale decision-makers.

The data requirements of an assessment depend on what specifically is being analyzed, and a multiscale assessment that integrates various levels of analysis necessarily requires the appropriate data sets. A wide body of data could be brought to bear on efforts to conduct multiscale assessments. However, the available information is often in a nonscientific format and must be processed for use in an assessment (for example, Gariep Basin). Moreover, the assessment may require not only data along spatial dimensions, but also data collected along a temporal dimension (that is, historical data) for a richer representation of the ecosystems analyzed. Developing a representative temporal data set for any area is a difficult task that is constrained by data availability and quality.

Even where large ecological and social data sets are available, there is often a mismatch among formats that makes the analysis of these joint data sets difficult, if not impossible. The design criteria of data independence across multiple scales in SAfMA precluded certain data-sparse regions from analysis, such as the areas of the Gariep Basin that extend into Namibia and Botswana. Data acquisition for these regions would have required the use of larger regional or global data sets and would have compromised the design criterion of scale data independence (SAfMA Gariep).

Additionally, an effective assessment involves interactions between the experts and the users of the assessment. The focal questions addressed in an assessment, and the scale of analysis used to address those questions, is dynamic and may change somewhat during the course of an assessment. Several MA sub-global assessments experienced this process of "adaptive scaling." For example, in Tropical Forest Margins, the scale of analysis was expanded during the course of the assessment from an initially highly local focus (for example, assessing the impact of burning when clearing agricultural land on soil nutrients) to include meso-scale assessments of smoke pollution and the implications of forest patchiness for biodiversity, and macro-scale assessments of carbon sequestration. The original design did not completely engage all users, and needed to be expanded to meet user needs.

4.4.1.1 Improved Analysis of Scale-Dependent Processes, Cross-Scale Interactions, and Causality

The most important drivers of ecosystem change identified in the various sub-global assessments differed across scales of analysis. (See Chapter 7.) For example, at a local scale, the frequency of droughts was considered a critical indirect driver of ecosystem change (since it affects water management strategies and agricultural production systems, which are seen to be the direct drivers of change). At coarser spatial scales, climate change was considered a key direct driver of ecosystem change (since it is a result of other indirect drivers such as per capita energy consumption) (SAfMA Gariep). Such a shift in emphasis about the role of drivers is typical of hierarchical systems but also emphasizes the different ways in which a single driver can manifest at different scales. This phenomenon is important when considering the most appropriate responses or policy interventions for mitigating impacts on ecosystem services at various scales. Further evidence for the changing nature of ecosystem drivers was offered by the Portugal sub-global assessment:

> *At the local scale it is usually very clear what the most important direct drivers of ecosystem change are, and how those drivers are going to evolve in the short term. This assessment is more difficult at the national scale. Some ecosystem services are also scale-dependent. For instance, a forest bordering a basin can*

play an important role in the water cycle, but this role only becomes apparent at the basin scale, not at the local scale. (Portugal)

The changing set of causal factors of tropical deforestation was also highlighted in the Tropical Forest Margins sub-global assessment. In this case, the assessment team noted the various scales of drivers for observed patterns of deforestation:

Shifting cultivation for subsistence food production is seldom the main cause of tropical deforestation. Other forms of agricultural expansion—practiced by smallholders and large landowners alike—tend to be much more important. But the most significant determinant of all is how these land uses interact with, and are affected by, macroeconomic forces, access to markets, and a host of other policy and institutional factors. (Tropical Forest Margins)

4.4.1.2 Reliability and Accuracy of Findings

The initial expectation, that drawing from views at multiple scales would yield a progressively better understanding of the relationship between ecosystem services and human well-being, was borne out in the sub-global assessments. Already mentioned is the SAfMA experience that incorporating local scales into the assessment increased heterogeneity in the identification of food shortages. Another example is that regions identified in the MA global assessment as suffering from water shortages were confirmed in finer scale assessments (see Chapter 8), thereby providing considerable support for the findings of each assessment (for example in SAfMA Gariep, San Pedro de Atacama, India Urban, Western China, and Laguna Lake Basin). In contrast, should the areas of water scarcity identified change across scales, assessment teams would be compelled to explore the possible reasons for such discrepancies, such as data or model inaccuracies, or alternative livelihood strategies that nullify broad-based patterns (for example, access to subterranean water sources in areas that possess limited surface water). In summary, the degree of confidence in the conclusions drawn from an assessment can be determined by the degree of consistency of findings (spatial or temporal) between assessments at different scales. Where a *comprehensive* multiscale assessment is conducted, the confidence in identified relationships and patterns across scales, whether positive or negative, is strengthened.

4.4.2 Impact Benefits and Costs

The primary goal of the sub-global assessments was to meet the needs of decision-makers at the scale at which they were undertaken, and in so doing, to inform and influence policy, management, behavioral, and institutional decisions. Given the status of the sub-global assessments, many of which are still in their implementation phase, it is not possible to judge what their final impact will be. This discussion therefore focuses on the ways in which conducting multiscale analysis facilitates an assessment process, rather than its potential impact. Even for the completed assessments, it is still too early to offer insights into the degree to which assessment outcomes will be incorporated into users' decisions-making processes.

4.4.2.1 Relevance of Problem Definition

For assessment findings to apply to a specific locality requires not only that information be collected and disseminated at a local scale, but also that local stakeholders be afforded the opportunity to target assessment questions to their specific needs. This proved particularly important in the face of varied definitions of human-well being at the local level. (See Chapters 5 and 11.) Participatory methods to generate an indigenous perspective on ecosystem services in Bajo Chirripó, for example, prompted the assessment team to focus on the well-being needs of local communities. This required that the analysis and results be presented in a fashion consistent with the world view of those communities, including due consideration of (1) the view that human beings are an integral part of habitats and habitats are part of human beings; (2) the belief that reciprocity exists among human beings (men–women, children–elders) and with the environment; and (3) the idea that the respect granted all of society is based on codes, norms, myths, beliefs, and dreams (Bajo Chirripó).

Similarly, increased relevance to local people was also attained within the Gariep Basin assessment, which initially paid little attention to the ongoing HIV/AIDS epidemic beyond its potential impact on demographic parameters. It soon became clear through interaction with the user group, however, that the social ramifications of HIV/AIDS were of paramount importance and should be more explicitly addressed in the assessment. A lack of attention and responsiveness to such identified needs would have had serious consequences for the legitimacy of the report in the eyes of the user community (SAfMA).

4.4.2.2 Relevance of Assessment Findings

The acid test of any assessment is the degree to which society ultimately assimilates the results of the assessment into its regulatory frameworks and livelihood practices. However, there is frequently a temporal mismatch between the time frame for decision-making (days to months) and the time frame for the research and assessment that may be needed to adequately inform decisions (years). Assessments play a valuable role in assimilating large bodies of recent scientific information in a more useful form for policy-makers. Many decisions can be taken even in the absence of full information and understanding; for example, a decision-maker might act to put in place a monitoring and management system for a previously unmanaged ecosystem service even before full information about that service is available. The proactive approach taken by the MA is therefore appropriate, as it attempts to anticipate the requirements of decision-makers. The pursuit of a U.N. resolution to create an appropriate international management framework for the Caribbean Sea is a case in point (Caribbean Sea).

Whether a user or decision-making community has the ability to respond to assessment outcomes is significantly influenced by that community's overall understanding of the nature of the problem and whether opportunities for

action existed prior to the launch of the assessment. Where the community is well-informed, an assessment may be able to provide specific information that can directly shape decisions. In contrast, when the issues are not familiar to the user community, the assessment may serve primarily as a tool for increasing overall understanding and awareness of the problems and options for responding. For example, the scientists and administrators involved in the Southern Africa assessment readily understood that climate change was a driver of change in the ecosystems in the region, but this was not known, and came as a surprise, to some of the local communities (SAfMA Gariep). These different perceptions and levels of understanding stem from differences in access to information among sectors of society, often within the same communities; in Bajo Chirripó, for example, young community members held views about ecosystem services that were very different from those of their village elders. Moreover, the ability of the general public to absorb novel information may be very slow.

4.4.2.3 Benefits of Scenarios Analysis

The benefits of designing scenarios at multiple scales are outlined in detail in Chapter 10 of this volume. The construction of scenarios at multiple scales allows an assessment to focus on the key uncertainties most important to stakeholders at a particular level. Key uncertainties at the global scale are not necessarily the most important uncertainties for decision-makers in a particular region or community, nor are the time scales that are typically considered at the global scale (50–100 years) very meaningful to decision-makers at the local community level. For example, a key uncertainty considered by the MA Scenarios Working Group at the global level was the degree to which technology can serve as a substitute for ecosystem services over the next 50 years. Within the southern African region, this was considered a relatively unimportant question within the 15–30 year time period of interest to local and regional decision-makers. The key uncertainty with respect to ecosystem services in southern Africa over the next two to three decades was identified as the effectiveness of governance in the region. It is interesting that governance emerged as a key uncertainty at all scales of the southern Africa assessment, although the particular form differed by scale. In SAfMA Regional, the key uncertainty revolved around national and transboundary governance structures and processes. At the local community level, the uncertainty centered on the effectiveness of municipal and community level governance (SAfMA Livelihoods, SAfMA Gariep). In general, key uncertainties of interest and importance tend to differ by scale.

4.4.2.4 User Ownership and Capacity Building

The sub-global assessments developed a number of design strategies to increase user confidence in the assessment findings. These strategies included:

- *Focusing on the local level.* One benefit that an assessment can provide is to contribute to repairing the broken trust between local communities and other stakeholders. The assessment's contribution is in providing relevant scientific information on key issues of importance to users. In San Pedro de Atacama, for example, where global demand for minerals and national demand for tourism revenue collide with local needs for reliable water supplies, the project design chose to bolster the ownership benefits of the assessment at the local level.

  Given the existence of clear and defined bodies of political decision-making in the different scales identified, the project decided to concentrate on and collaborate with local institutions, in order to strengthen their potential impact on the decisions the project might influence. This decision was also motivated by the local community's growing distrust and conflict with both the public and private sector. It was therefore considered more important to strengthen existing organizations, rather than create new ones, and so contribute to increasing awareness of the environmental issue in the very heart of such institutional arrangements. (San Pedro de Atacama)

- *Providing a multistakeholder forum where public and private actors jointly discuss important issues for the assessment area.* This can be done by incorporating representatives from various agencies and interest groups into the advisory board of the assessment. In the Laguna Lake Basin assessment, this approach was used to include key people in a position to most effectively generate appropriate interventions and mitigation actions (KM–Laguna Lake Basin). Similar measures to increase the network and communication links among relevant stakeholders were utilized in a Swedish sub-global assessment:

  The central actor—EKW at the municipal level—has chosen to limit its concern to the social-ecological system at the municipal scale. A catchment scale would appear more logical but EKW did not have the political mandate, nor the resources, to initiate a collaborative learning process for ecosystem management at that scale. Now that we (Stockholm University) are part of the network we might be able to broaden the social-ecological scale. (Sweden KW)

Increased understanding of multiscale interactions resulted in increased awareness that sectors of society operating at different spatial and temporal scales often place competing demands on ecosystem services. In practice, this means that difficult trade-off decisions have to be made in terms of allocating limited resources to serve multiple human needs. Negotiated solutions to environmental resource tensions are not always easy to achieve, and power relations among various groups may be significantly skewed. In several cases, the ecosystems upon which communities depend are being systematically exploited by more powerful agents (Coastal BC, PNG, San Pedro de Atacama). The collapse of abalone populations along the coast of British Columbia is a case in point: when breeding locations, sustainably harvested for generations by First Nations, were opened to commercial fishing interests, it led to a total collapse of this ecosystem service (KM–Coastal BC). Although it is often argued that such large developments often serve the greater good, for example, regional development and/or national economic gains, communities involved in the

sub-global assessments often did not share this view. (See Chapter 11.)

4.4.2.5 More Balanced Assessment Results

Based on the experience obtained to date in the uptake of assessment findings, there is evidence that a multiscale structure did improve the impact of assessment results by more directly meeting the user needs of specific areas. For example, in the southern Africa assessment:

> *The larger scale studies provided the broader context for some of the findings at smaller scales, while the smaller scale studies served to ''ground-truth'' regional findings and provided more detailed understanding of some of the broader scale findings. In addition, different scales contributed an understanding of different processes (e.g., it is meaningful to study fuelwood at the regional and local scales, but less so at the basin scale), or alternative views of the same process as seen differently by stakeholders at different scales (e.g., ecotourism at the regional as opposed to the local scale). (Scholes and Biggs 2004)*

4.5 Lessons Learned in Conducting Multiscale Assessments

The various sub-global assessments explored here were derived from distinctive needs, interests, and capacities; undertaken at different locations and over different time frames; and involved different stakeholder groups. The scales of analysis and systems of observation selected were uniquely shaped by the circumstances and people involved in each assessment. Perception is key, but so are the spatial and temporal scales through which perception is achieved and analyzed. The sub-global assessments thus came to combine scales of observation and scales of analysis, often in mutually informative ways. (See Box 4.5.) This iterative process of conducting an assessment at multiple scales was highlighted in the Tropical Forest Margins sub-global assessment report:

> *In some cases, this process of identifying the appropriate scale for analysis and reporting has been a research activity in itself extending over a period of several years. (Tropical Forest Margins)*

Although the sub-global assessments represent a wide variety of environmental and socioeconomic conditions, the lessons learned from conducting assessments under a common conceptual framework at each of these sites offered valuable insights about the design and implementation of a multiscale assessment. Additionally, the MA sub-global assessment experiment generated a wide range of innovative ideas, as well as lessons and pointers toward best practices that could be useful for conducting assessments in the future. (See Chapter 6.) Best practices are discussed throughout this volume; however, the unique nature of multiscale assessments offers additional insights and solutions that are peculiar to a multiscale assessment. The following sections synthesize the lessons learned across the sub-global assessments in conducting multiscale assessments and offer a discussion of methodological innovations for conducting an assessment at multiple scales that emerged from the assessments.

4.5.1 Conducting Multiscale Assessments

The MA conceptual framework assumes that the continued provision of ecosystem services requires mutually supportive responses at multiple levels and that, in general, effective management of ecosystem services requires responses at many different scales (MA 2003). This perspective was confirmed in the Southern Africa assessment:

> *The different scales were chosen to make it possible to investigate processes at the scales at which they take place; to take into account feedbacks between scales; to help ensure that perspectives at any given scale are reflected in the analysis and conclusions at other scales and to allow evaluation of the scale dependence of various actions and policies and to meet the needs of different users. (Biggs et al. 2004)*

Conducting a multiscale assessment presents a significant challenge for several reasons, including difficulties associated with bringing together multidisciplinary teams, issues related to data availability, methodological challenges, and a lack of integrative scale-independent theories. The task of an assessment team is to choose a set of focal scales that correspond best with the key concerns of the study area by considering the following:

- user needs at different scales,
- local context and extent of ecosystem services considered,
- assumptions about the nature of the relationships between observed patterns and the drivers of change in the assessment area, and
- available data and time constraints.

Given the difficulties that must be addressed in a multiscale approach, the collective experience of the sub-global assessments indicates that there are some times when a multiscale assessment is absolutely necessary. At other times, however, even though a multiscale approach or analysis would provide useful informtion, it is not necessarily required to achieve the desired outcome. Making this a priori decision is difficult, but the inclusion of at least one scale of analysis (the scale most relevant to the dominant ecosystem services and decision-making levels) between global and local assessments generally appears to be beneficial.

A multiscale approach can be considered absolutely necessary under any of the following conditions:

- when the relevant definition of the problem assessed and/or the specific objectives of the project dictate a multiscale approach;
- when response and policy-prescriptive mechanisms for coping with changes to ecosystem services depend on syntheses and theories that link data from various scales of analysis into a coherent picture of how to better manage ecosystems for human well-being;
- when understanding causality and/or who wins and loses under current circumstances (or under possible policy options) is important to the users of the assess-

BOX 4.5

Multiscale Assessments: Some Emergent Challenges

Multiscale interactions, although understood to be important, present significant scientific challenges in both observation and explanation. The MA provides a valuable comprehensive review of these issues (MA 2003). Theories of observation have profound histories in philosophy, statistics, and linguistics, each of which has focused in its own ways on how people create categories to distinguish among measurable realities they perceive to be significantly different from one another. Because such categories change, even for one person, with context, mood, technology, need, and purpose, the choice of any one category necessarily precludes the informational opportunities available if categories, scales in this case, were chosen in another moment or place or with different tools and purposes. To one extent or another, the observation embodies the observer and the conditions shaping the observer's perception.

The scientific challenge is to identify, reduce and even eliminate the bias this introduces to observations. Theories of statistical sampling, language formation, and econometrics, among others, provide particular insight into the complexities of the problem and ways to overcome them. Today advances in measurement techniques and computational capacity are enabling the generation of numerous differently scaled observations, simultaneously and over time, and their use in iterative searches for patterns of relationship that emerge within and among observational scales.

Hierarchy theory, which is one current body of knowledge upon which the MA has relied to assess cross-scale processes, is restrained by observational limits. But if such limits did not exist, there are even more formidable problems in the measurement and explanation of processes which, as contrasted with objects, are intrinsically mobile and therefore particularly prone to distortion when efforts are made to hold them still, however momentarily, for a look. Moreover, processes are themselves identified by categories of the behavioral theories (for example, adaptation and evolution) that define them as significantly distinctive behavioral relationships.

Today, such explanatory challenges have created a new scientific openness to the wide variety of modes of explanation existing throughout the world. Interdisciplinary and cross-cultural inquiry, such as the MA has fostered, perhaps on a uniquely ambitious scale, is one part of this development. So, too, is the empowerment of discussion about modes of explanation that have developed outside the culture and interests of the Western scientific tradition.

For the MA sub-global assessments, user concerns, needs, and data availability defined the changing set of scales of observation and explanation among the assessments, and within assessments over time. This reduced opportunities for comparability and meta-analysis while revealing the immense observational and explanatory variability that exists over the world and that a global assessment alone would not capture. In the future, perhaps the emerging richness of observational method will be joined by equivalently rich mobility among conceptual frameworks and the processes it can begin to reveal and explain.

ment. For example, a global assessment is sufficient to identify whether humans have an impact on stratospheric ozone. However, to understand which countries are causing the problem or to understand who is most at risk from depleted ozone concentrations, a multiscale analysis would be essential; or

- when the presence of assessments at multiple scales will significantly increase the ownership of the assessment findings by users at those scales.

Even though a multiscale approach may be potentially informative, it is not always necessary to achieve desired outcomes. Many sub-global assessments produced information useful to their stakeholders without carrying out a multiscale assessment or undertaking multiscale analyses. This was the case either:

- when the costs (in monetary terms or in terms of the difficulties) outweighed the potential benefits to be gained from conducting an assessment or analyzing information at multiple scales; or
- when a single scale of analysis best corresponded to the problems, objectives, and/or decision-making structures of the assessment. For example, the Kristianstad Wetlands assessment focused on a localized geographical problem that did not require extensive regional analysis to achieve the required outcome (Sweden KW).

These points notwithstanding, the evolving nature of the sub-global assessments may at some point in time require the incorporation of additional scales of analysis into the assessments. As data become increasingly available, more widespread and efficient analyses will likely develop. Indeed, many sub-global assessments indicated explicit intentions of scaling up the assessment process in the future (KM–India Local, Vilcanota, Colombia).

4.5.2 Evolving Scale-related Issues

When there is an obvious need for a multiscale assessment, and the multiscale design has been agreed upon, a number of issues need attention when conducting the assessment:

- *Evolving user needs.* User needs are not static, even over short time scales. The assessment needs to provide opportunities for users to engage with the assessment at regular intervals to accommodate this dynamic and to re-assess user needs as necessary.
- *Emergent mismatches.* Irrespective of how carefully an assessment is designed, the designs may not always turn out to be practical, and surprises may crop up, requiring some flexibility and adaptation. Tropical Forest Margins found the initial assessment scales to be insufficient for capturing important drivers relevant to understanding tropical forest conversion; the assessment strategy was subsequently adapted to incorporate these drivers.
- *User engagement.* The need for active user engagement increases as assessments become more fine-grained and are more intimately involved with the needs, aspirations, and dynamics of local communities. This process of user engagement can be extremely time-consuming and resource-intensive. Time constraints made it challenging to maintain the required user group and stakeholder involvement while conducting sub-global assessments. For a comprehensive discussion of the requirements, dynamics, and examples of an effective participatory process in environmental science, see Younge and Fowkes

(2003). This feature of incorporating effective stakeholder engagement models in assessments is one that needs to be improved in future assessments.

4.5.3 Multiscale Sub-global Assessments as a Source of Innovation

The sub-global assessments were important sources of innovation in conducting multiscale assessments, prompting both new analytical tools and new institutional response mechanisms.

The sub-global assessment experience emphasized the need for tools and approaches to deal with issues at widely differing scales, as well as for integrating across scales. It also suggests that it is feasible to develop analytical methods that not only are consistent with the goals of a multiscale assessment, but that can also significantly enhance the multiscale assessment process over space and time. SAfMA, for instance, developed a scale-independent index (the Biodiversity Intactness Index) to measure and compare biodiversity across the various scales of analysis. (See Box 4.6.)

A number of sub-global assessments developed innovative institutional response mechanisms. (See also Chapter 9.) While some sub-global assessments viewed broadly defined ecosystem management initiatives such as the Convention on Biological Diversity as remote mandates requiring relatively few responses at the local level, others saw these initiatives as opportunities to develop innovative and cooperative response arrangements, for example, between villages, state agencies, indigenous groups, international and national NGOs, and corporations, in combination with distinctive places, problems, and political cultures. The People's Biodiversity Register, developed in response to the CBD by India Local, is a case in point. Other examples include San Pedro de Atacama, Laguna Lake Basin, Sweden KW, and Sweden SU. Although innovations were initially developed at localized scales, they are beginning to transform the way societal response management options and impacts are viewed at coarser levels (India Local, Caribbean Sea). What this means for organization, knowledge, and technologies for the future management of ecosystem services deserves further consideration.

4.6 How Do Sub-global Assessment Results Inform Global Assessments?

The extracts and examples provided thus far from the sub-global assessments have important implications for a number of scale-related findings, hypotheses, and statements generated from a global assessment perspective. Evidence from sub-global assessments that inform global findings are highlighted below; they emphasize that drawing from both views (global and sub-global) presents an opportunity to gain a progressively better understanding of the role of ecosystem services for human well-being.

Global forces, local impacts. The sub-global assessments found that global forces significantly affect the magnitude and quality of ecosystem services through all scales of human activity down to farm and household levels (Caribbean Sea, Northern Range, San Pedro de Atacama, SAfMA Gariep, Tropical Forest Margins). Particularly influential are global markets, trade, climate and human activities affecting it, and shifts in the global political order from the bipolar world order (rich–poor, industrial–developing) toward diffused and regional representations.

Climate variability, climate change, and biodiversity risk avoidance. The sub-global assessments, almost unanimously, recorded concerns about the threats of climate variability and climate change, and of these, almost half also documented concerns about threats to biodiversity and the livelihood consequences for people (India Local, SAfMA Gariep). This concern is shared with the global assessments that emphasize the importance of risk avoidance in managing ecosystem services. This suggests that concerns about climate variability and climate change and biodiversity loss are pervasive among people from all walks of life, even those that operate at very different scales. This means that the fulfillment of the Kyoto agreement and CBD aspirations has broad relevance across scales.

Food production trade-offs, risk, threats, and insecurity. The importance of the fundamental trade-off between the need to increase food production and the need to sustain, in the long run, the capacity of ecosystems to support food production is enriched by further trade-offs that gain particular importance at sub-global and local scales. These trade-offs exist:

- between the needs to increase food production and to secure a minimum livelihood in uncertain market, climate, and political conditions (Argentine Pampas, Tropical Forest Margins);
- between the needs to increase food production and to distribute it to secure minimum needs (Altai-Sayan); and
- between equitable distribution of food and the sustainability of environmental productive capacity (SAfMA Gariep).

Evidence from the sub-global assessments suggests that people devalue the consequences of their actions on future generations or other scales when their security of life and livelihood is threatened and that people are likely to avoid commitment to altered resource management regimes if they perceive their returns as vulnerable or variable (Caribbean Sea, Tropical Forest Margins, SAfMA Gariep). Such perceptions have obvious implications for developing appropriate responses to agricultural resource degradation at a local scale where immediate needs have to be addressed explicitly.

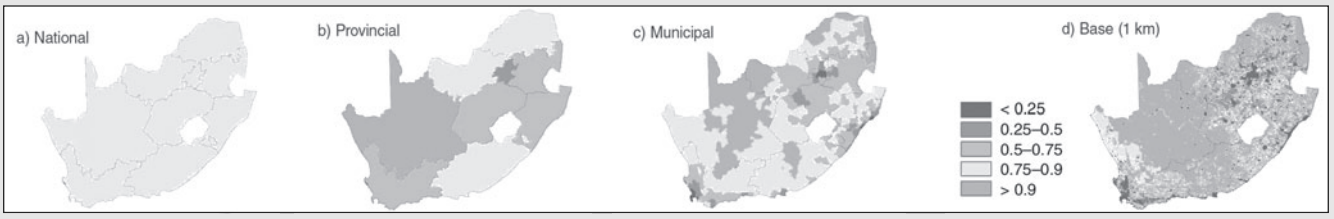
Evolution of governance arrangements and institutional responses. The sub-global assessment results showed that effective institutional and governance arrangements evolve in response to site- and culture-specific conditions and extreme events for a whole range of ecosystem services, from forests, water, and soil to the resolution of urban land use conflicts (Sweden KW, Sweden SU, San Pedro de Atacama, Colombia, Vilcanota, KM–Laguna Lake Basin). This expands on the MA conceptual framework's view that institutions are primarily mechanisms for implementing policies, not emergent responses in their own right (MA 2003).

BOX 4.6

Assessing Biodiversity at Multiple Scales: SAfMA

The MA considers biodiversity—the total variety of life at the genetic, species, and ecosystem levels (MA 2003)—as a condition necessary for the "delivery of ecosystem services" by virtue of the many feedbacks that exist between biodiversity and global environmental and biophysical variables (Brown and Maurer 1989; Chapin et al. 1998; Kleidon and Mooney 2000; Zavaleta et al. 2003). The extent to which biodiversity contributes to the delivery of ecosystem services for human well-being depends on the relationships between a complex set of factors (climate, geomorphological processes, etc.) operating simultaneously at various scales. The currency of these relationships includes biomass, water, trace gas exchange, plant and animal movements, and productivity (Botkin et al. 1984). Certain ecosystems may serve as sources of materials or energy, while others may serve as sinks (Pulliam 1988). Information on the state of biodiversity is therefore of importance to policy-makers concerned with managing ecosystem services. Existing measures of biodiversity, in particular species richness, are heavily scale-dependent, making it difficult to compare results at different scales.

SAfMA developed a new index of biodiversity condition (the Biodiversity Intactness Index) to assess changes in species abundance at the different scales of the assessment (Biggs et al. 2004). The index, represented below at three special scales (national, provincial, and municipal), aggregated from the base resolution of 1 kilometer (d), permitted direct comparison among results obtained at different scales (extent and resolution) of analysis. The index can be applied using species richness (distribution) data of varying resolution; it is robust to reasonable differences in the interpretation of land use classes.



The Biodiversity Intactness Index applied at sub-national levels of environmental decision-making in South Africa. The overall score for South Africa is 81.2%. Results are richness- and area-weighted averages of BII as estimated at a base resolution of 1×1 km. Values of BII obtained at different scales are directly comparable: they refer to the average abundance of all species in the particular area, expressed as a fraction of pre-colonial era abundance. (Biggs et al. 2005)

In addition, the sub-global assessments showed that management increasingly involves not just a local group and the government, but a range of stakeholders that acknowledge overlapping systems of management and diverse interests. This applies to institutional responses across sectors as diverse as water (KM–Laguna Lake Basin), watershed management (SAfMA), biodiversity (India Local), and metropolitan management (Sweden SU, KM–São Paulo). In other words, cross-scale institutional processes are much more common than might be expected from a single-scale assessment and may well be the means through which the variations in climate and markets are absorbed and risks are spread to secure effective commitments to problems of ecosystem services and human well-being.

The role of markets, trade, and the environment at the local level. Some sub-global assessments indicated that people are primarily concerned with avoiding risks that threaten their security and livelihoods (SAfMA Gariep; Tropical Forest Margins; KM–Bajo Chirripó; Alejandro Argumedo, personal communication, Vilcanota). This could explain the emergence of local decisions that at first glance appear to contradict economic predictions. For example, local communities will protect sacred groves as species reservoirs through exploitation taboos in the face of economic hardship or famine—a risk-avoidance mechanism that ensures continued access to these species in the future (SAfMA Gariep).

Moreover, the sub-global assessments revealed penetrating influences of market price relationships on human activity and ecosystem services (PNG, San Pedro de Atacama, SAfMA Gariep). Emanating from integrated global commodity markets, these relationships guide local crop and natural resource management choices (Coastal BC, Portugal, SAfMA Gariep, Tropical Forest Margins, Colombia), distributions of intensive and extensive activities (SAfMA Gariep, Tropical Forest Margins), and balances between the

build-up and drawdown of environmental capacities. For example, significant declines in crop prices (due to combined effects of global commodity price changes and changes in currency values) can lead to rapid changes in land use practices. This dynamic was evident in the case of coffee producers in Colombia, where the market value for coffee plummeted from $2.00 per pound in 1986 to $0.64 per pound in 1987. People shifted from coffee production to cattle ranching, expanding the production areas into sensitive ecoregions (resulting in 19% and 25% reductions in forests and the fragile ''paramo'' ecosystems, respectively) (Colombia).

Changing market conditions, combined with increased availability of employment alternatives, can also result in a shift of labor away from traditional resource management activities. This labor mobility can harm local ecosystem services (for example, if smallholder farmers move to cities and sell unwanted land for use in intensive agriculture). Or it can enhance ecosystem services if it leads to a reduction in harvest pressure on a natural resource (such as reducing fishing pressure). In the Downstream Mekong and Bajo Chirripó sub-global assessments, the negative impacts predominated. In Viet Nam, for example, conversion of mangroves to shrimp farming has increased local incomes, but at considerable cost to these ecosystems (Downstream Mekong).

Local processes, global impacts. The sub-global assessments highlighted a number of instances where local factors (such as responses and drivers) can achieve global significance, although time lags (that is, the time it takes for these forces to be noticed at coarser scales) and market mechanisms may obscure this process. In some sub-global assessments, such processes have begun to facilitate cross-scale sharing of knowledge and information, largely through initiatives by civil society to influence national and even regional or global agendas. The Caribbean Sea assessment team's pursuit of a U.N. resolution to designate the Caribbean Sea as an area of special importance is a case in point. In this case, the needs of local land users in independent countries (in the tourism or fishing industries, for example) were aggregated to achieve special consideration by a global body. Plans to protect the species listed in India's People's Biodiversity Register under the umbrella of intellectual property rights are another example of a local process that can achieve global relevance. What these sub-global examples imply is that the capacity to develop appropriate responses to changes in ecosystems can and often does emerge at very local scales—but their potential impacts may also be felt at much coarser scales.

Uncertainty. The sub-global assessments demonstrated the prevailing influence of uncertainty and insecurity as a driver of human actions across all spatial and social scales (SAfMA, Tropical Forest Margins, Northern Range). Individuals are more likely to invest in long-term sustainable management of a resource under conditions where they have relatively high confidence that those investments will provide a return. This in turn requires relatively stable commodity prices, secure rights to resources, and a predictable regulatory and institutional structure. One factor influencing the perception of uncertainty and insecurity is the knowledge of local climate and ecosystem processes. Individuals with considerable local knowledge about variations in climate or ecosystem processes may perceive far less insecurity in standard environmental fluctuations than individuals without that local knowledge. Uncertainty and insecurity are thus key factors shaping the responses of individuals and communities to ecosystem changes. An appropriate response thus cannot be developed based only on projected future trends; instead stakeholder perceptions of uncertainty also need to be gauged and managed.

Global political order and emergent innovations. Two global political trends appeared to be important in all of the sub-global assessments. The first involves the tensions inherent in the reality of today's bipolar (rich versus poor) world order, and the ensuing diffusion and regionalization of power (trade blocs) (see PNG, San Pedro de Atacama, Coastal BC). Second was the emergence of nongovernmental interests as agenda-setters on a global stage, exerting significant influence on issues such as climate change, biodiversity, forests, water, and endangered species. In effect, ecosystem services are emerging as a unifying force on a global scale, while traditional forms of unification (for example, nationalism) are declining. The consequences for ecosystem services remain uncertain.

In sum, the diversity among sub-global assessments in terms of problem definition, objectives, scale criteria, and systems of explanation increased as the focus on local scales of assessment increased. Processes and issues of common concern assumed different meanings and implications at different scales. This was particularly apparent in three common areas of concern within all sub-global assessments:

- *market forces,* which at global scales govern broad allocations of resources, such as the increase or decrease of forest cover, but at localized scales determine livelihood strategies, security, and protective organizational, technical, employment and migration responses;
- *environmental degradation,* which at global scales addresses phenomena like climate change and biodiversity loss but toward local scales becomes increasingly tied to a complex web of trade-offs associated with the provision of ecosystem services upon which livelihoods depend; and
- *perceptions and uses of institutional channels* through which ecosystem services might be enhanced, from global agreements and financial commitments to cooperative local resource management and indigenous advocacy.

Comparison among scales of an apparently common problem produced a much richer sense of the problem and how to respond to it.

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Chapter 5

Using Multiple Knowledge Systems: Benefits and Challenges

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Main Messages ***87***

5.1 Introduction **87**

5.2 Knowledge Systems **89**

5.3 Benefits of Using Multiple Knowledge Systems in an Assessment . . . **93**
5.3.1 Information Benefits
5.3.2 Participation as a Means to Empowerment for Local Resource Users
5.3.3 Use and Application of Findings

5.4 Design and Process for Incorporating Multiple Knowledge Systems **102**
5.4.1 MA Design: Guidelines for the Use of Multiple Knowledge Systems in Sub-global Assessments
5.4.2 The MA Process: Incorporating Multiple Knowledge Systems
5.4.3 The Influence of Different Knowledge Systems
5.4.4 The Utility of the MA Conceptual Framework for the Assessments
5.4.5 Knowledge Systems, Institutions, and Scale

5.5 Lessons Learned: Incorporating Multiple Knowledge Systems in Future Assessments **111**

REFERENCES **115**

⋆When citing this article, please list both authors' names, as they share lead authorship.

BOXES

5.1 Ethical Protocol for the Use of Local and Traditional Knowledge in Assessments

5.2 State–Local Interactions and Their Impact on the Transmission and Validity of Local Knowledge: South Africa

5.3 Adaptation of Traditional Ecological Knowledge for Resource Management: Bajo Chirripó

5.4 Constructing a Conceptual Framework for Quechua Communities: Vilcanota

5.5 Complexity in Scenario Development: Wisconsin

TABLES

5.1 Local and Traditional Knowledge (LK) Use by Selected Sub-global Assessments

5.2 Participants and Their Roles in Selected Sub-global Assessments

5.3 Methods Used to Incorporate Multiple Knowledge Systems in Selected Sub-global Assessments

5.4 Contributions of Various Knowledge Systems to Selected Sub-global Assessments

5.5 Institutions, Scale, and Knowledge Systems in Selected Sub-global Assessments

Main Messages

The MA sub-global assessments were structured to encourage the use of multiple knowledge systems across scales, including the disciplines of scientific knowledge, practitioner (or assessment user) knowledge, and local/traditional knowledge. The multidisciplinary framework and assessment teams enabled the contribution of different facets of scientific knowledge; multistakeholder teams facilitated the sharing of practitioner knowledge; and the involvement of local resource users allowed for sharing local and traditional knowledge in several cases. There was more information, and thus analysis, from the assessments on the use of local and traditional knowledge than there was on multidisciplinary or practitioner knowledge.

Practitioner knowledge, the diverse knowledge of multiple stakeholders, contributed more in terms of information needs and expectations than in terms of ecosystem management knowledge. Few assessments had significant analysis of the contribution of practitioner knowledge to the assessment. However, the Sweden KW assessment was structured so that practitioner knowledge was fully integrated within the assessment process. In the Tropical Forest Margins assessment, practitioners became more integrated over time as there were intensive efforts to encourage stakeholder participation. Most other assessments encountered problems in utilizing practitioner knowledge, in many cases because practitioners were viewed as users of the assessment results instead of knowledge holders in their own right. Engagement of assessment users and other practitioners as knowledge holders requires more attention to how knowledge is used in policy, decision-making, nongovernmental organizations, and bureaucratic practice.

Local and traditional ecological knowledge added significant insight about locally important resources and management practices, revealing information and understanding that is not reflected in the global assessments. This included information about: names and uses of locally important plant species and practices to protect them (for example, India Local and Sinai), local drivers of change (SAfMA Livelihoods), specialized soil and water conservation practices (India Local), and coping strategies to protect human well-being (Sinai, SAfMA Livelihoods, Sweden KW). Local resource users also contributed valuable long-term perspectives about their social-ecological systems (Bajo Chirripó, Vilcanota), as well as information on key ecosystem processes that are important, uncertain, and difficult to control (Wisconsin).

The extent to which local and traditional ecological knowledge contributed to the assessments varied, due to local circumstances, the predisposition and expertise of the assessment team, and the resources allocated to understanding and using local knowledge. Local knowledge is both complex and inherently contextual, and a rigorous and comprehensive investigation and interpretation of local knowledge is needed to fully understand it in its own right. Collaborative relationships, such as those developed in Vilcanota, Peru, and Bajo Chirripó, Costa Rica, as well as participatory tools that broaden the level of enquiry, often result in the emergence of key issues of local importance. For example, in the Bajo Chirripó assessment, local participants found that much existing traditional knowledge about natural resource management strategies was being forgotten, so the assessment emphasized learning more about and reviving these management strategies instead of introducing new ones.

Sub-global assessments had to weigh the trade-offs involved in achieving tangible results versus working through the transaction costs of building a partnership consisting of different knowledge holders. Multidisciplinary and multistakeholder research involves considerable transaction costs. Working with local and traditional knowledge holders also requires time to build trust and equitable relationships. Recent work has shown that these costs are likely to decrease as social learning occurs and solid working relationships are established. In the Sweden KW assessment, transaction costs were low at the start of the assessment because of long-standing networks already in place.

The MA assumed that participation would empower local resource users in two ways: (1) through increased local ownership of the assessment process and results, and (2) through scientific validation of local knowledge, which would in turn encourage policy-makers to recognize and utilize it. However, as local participation varied from fully collaborative to extractive, so too did the potential for empowerment. At one end of the spectrum was the Vilcanota assessment, in which local resource users designed and directed the assessment process. At the other end was Western China, in which any local knowledge that was used was inserted into a scientific, state-imposed framework, making it difficult for the assessment to realize the full potential of local and traditional knowledge.

The sharing of knowledge across scales in the sub-global assessments did not occur to the extent hoped for by the MA. This was partially due to methodological issues such as uneven emphasis on different knowledge systems and problems with validation. The MA had developed procedural guidelines for validation of local and traditional knowledge at the local level, but the sub-global assessments often lacked adequate processes of validation for the use of local knowledge at higher levels. Mediating institutions or boundary organizations are usually necessary for this, and these were not present for a number of the assessments.

There is evidence that including multiple knowledge systems increased the relevance, credibility, and legitimacy of the assessment results. For example, in Bajo Chirripó, the involvement of nonscientists added legitimacy and relevance to assessment results for a number of potential assessment users at the local level. However, in many sub-global assessments, local resource users were not decision-makers, so the question of legitimacy became irrelevant in cases where they did not have the opportunity to use the assessment results.

Some sub-global assessments confirmed that local institutions have a role in conferring greater power to local knowledge holders in cross-scale decision-making. For example, in India Local and in Sweden KW, deliberate efforts were made to embed the assessment within existing institutions that link local knowledge to higher-level decision-making processes. However, in the SAfMA Livelihoods assessment, the local institutions helped to maintain knowledge but were too weak to enable local knowledge to be used in higher-level decision-making. The Vilcanota and Bajo Chirripó assessments attempted to create space to begin a dialogue between local communities and higher-scale decision-makers. The success of these efforts can only be evaluated with more time.

5.1 Introduction

This chapter assesses the experiences of the MA sub-global assessments in using multiple knowledge systems to examine the relationship between ecosystem services and human well-being. The chapter also reflects on the benefits and challenges of involving multiple knowledge systems in conducting such assessments. The intellectual and practical basis for linking multiple knowledge systems is well established, as are the difficulties of making these links in practice (Agrawal 2002; Nadasny 1999).

Recently, the incorporation of multiple knowledge systems into integrated assessments of environmental and social status has been established as critical (Pahl-Wostl 2003;

Lawrence and Elphick 2002). The MA was concerned with including multiple knowledge systems in the sub-global assessments for several key reasons (MA 2003).

- Linking human well-being to ecosystem services implies that the perspectives of and information from local (usually interpreted to mean community or village level) residents and users of the ecosystem are important to understand. Local people have particular knowledge about the ecosystems that they live and work within, as well as their own associated well-being, that others do not.
- Ideally, an assessment at any given scale should meet the needs of resource users and managers at that scale, who should be involved in defining the issues of concern. Thus local level management depends on the voices of local people, which are all too often not heard, or else are ignored or misunderstood.
- The use of multidisciplinary and multistakeholder perspectives is important in order to understand the links between ecosystem services and human well-being; an assessment is usually enhanced when informed by a variety of research, scientific, or other perspectives. Just as people from different locations speak a different language and express their ideas differently, so do scientists trained in different disciplines and people working in different organizations (NGOs, development agencies, etc).
- The gap between research and policy is often recognized but rarely solved; exploring the differences in framing, representing, and legitimating knowledge among scientific researchers and policy/decision-makers will help to close this gap.
- The process of rigorous documentation and use of local and traditional ecological knowledge is often seen as empowering local resource users, as it can link them to decision-making at higher scales and possibly catalyze decision-making capacity at the local level. However, novel institutional arrangements are often necessary for this to occur.

Along these lines, the MA adopted several principles to guide the inclusion of multiple types of knowledge in the sub-global assessments (MA 2003):

- A good assessment must be scientifically *credible,* politically *legitimate,* and respond to the needs of decision-makers (*useful*). The MA attempted to strengthen the approaches of earlier assessments by investigating the links between ecosystem condition and human well-being at multiple scales, and according to the needs of a broad group of ''users.'' ''Users'' refers to those in a decision-making capacity who will use the results of the assessment (in contrast to ''resource users,'' which is defined as those who use local ecosystem resources). For assessment findings to be credible to decision-makers at other scales, the conventional definition of scientific credibility needs to be broadened so as not to exclude local knowledge, which is often not easy to validate in scientific terms but is subject to local methods of validation. The multiscale approach requires linking multiple knowledge systems, and credibility must be established in different ways.
- The MA explicitly valued local-level knowledge and recognized that local and traditional ecological knowledge provides information that is often not documented by science (used here to mean western science, modern science, formal science, or conventional science, rather than indigenous science). The MA was also designed to be policy-relevant. The MA sub-global assessments operated on the premise that assessments should be conducted at the level where decisions are made. For example, an assessment conducted at the national level may or may not be as useful to local people as an assessment conducted at the local level. The unique contribution of the multiscale framework is that it enables the use of multiple knowledge systems, including knowledge held by resource users, practitioners, decision-makers, and researchers.
- The MA aimed to empower local resource users, through the assessment process itself, by linking local and traditional ecological knowledge to decision-making at higher levels.
- By establishing a multiscale process with assessments conducted at the sub-global level, the MA conceptual framework promoted cross-scale knowledge sharing. Researchers have promoted the need for cross-scale interactions, or dialogue, between knowledge systems, in order to foster appropriate management for social–ecological systems (Cash and Moser 2000; Berkes 2002; Young 2002). This view recognizes that knowledge is embedded in institutions, which are located at particular social, political, and economic scales, because of how societies are structured.

The MA faced two main challenges when using multiple knowledge systems (Reid 2004):

- Who establishes what appropriate ''validation'' of information is?
- Can a scientific assessment like the MA ever be seen as ''legitimate, credible, or useful'' to indigenous communities or other individuals who hold different worldviews and use different standards for evaluating the utility of information?

Conversely, these questions may be asked: How can it be ensured that a scientific assessment that utilizes local and traditional ecological knowledge will be seen as credible within the scientific community? Can an assessment that caters to the needs of multiple users be truly legitimate to any user? The MA took steps to ensure broad legitimacy; this chapter examines the process of bringing together multiple knowledge systems within the MA sub-global assessments.

In recognition of these challenges, the MA organized an international conference in March 2004 on ''Bridging Scales and Epistemologies: Linking Local Knowledge and Global Science in Multiscale Assessments'' in Alexandria, Egypt. The conference provided a forum for much theoretical debate on the issues, and an opportunity for sub-global assessments to present how they dealt with using multiple knowledge systems. The conference included indigenous

groups' and local resource users' discussions of how they felt their specific cultural-based knowledge could be used together with science.

In general, the sub-global assessments used many different approaches to resolve the challenges of using multiple knowledge systems. This was, especially at the sub-global level, an experiment. This chapter explores the successes and difficulties faced in conducting this experiment. The chapter first summarizes conceptual issues surrounding the definition of knowledge. This is followed by a discussion of the benefits of using multiple knowledge systems in an assessment, drawing on the experiences of the sub-global assessments. The next section examines the design and processes used for incorporating multiple knowledge systems, and the final section highlights lessons learned.

Of the 34 sub-global assessments, 25 used either local or traditional knowledge. The examples used in this chapter are illustrative, pointing to trends among the sub-global assessments rather than quantified results. The tables, for example, highlight particular issues rather than summarize all the sub-global assessment results. The chapter presents information on the assessment process up to the end of October 2004.

5.2 Knowledge Systems

In order to understand why it is so difficult to ''link'' or to ''use'' different knowledge systems together for problem solving, some discussion of what underpins different kinds of knowledge is necessary. A knowledge system is defined, for the purposes of the analysis in this chapter, as a body of propositions actually adhered to, whether formal or otherwise, which are routinely used to claim truth (Feyerabend 1987). Knowledge is a construction of a group's perceived reality, which the group members use to guide behavior toward each other and the world around them. Knowledge systems have a social context and, in many settings, environmental knowledge is important to a group's identity (Milton 1996). Understanding knowledge as a ''context-dependent process of knowing'' requires an investigation and analysis of prevailing social norms, values, belief systems, institutions, and ecological conditions that provide the basis of a ''place'' where knowledge is applied (Woodley 2005). Knowledge may also be understood as a process of ''engagement'' (Ingold 2000), where through their actions people come to understand the world and what it affords them.

Working definitions in this chapter accept the premise that all knowledge is situated and partial. One knowledge system is never treated nor understood as inherently superior to another, nor is there a hierarchy in terms of the validity of different knowledge systems. These premises provide a consistent way to look at highly diverse knowledge systems, in order to understand the reasons that people have different yet equally valid explanations for what they observe in the world around them. Our exploration of knowledge systems includes an examination of published science, gray literature, user needs and understandings, and the knowledge of local resource users. The definitions below form the basis for discussion on how knowledge systems may differ and how a plurality of knowledge systems in an assessment may provide a firmer foundation for understanding the linkages between ecosystem services and human well-being. The definitions provide a simple platform for discussion of the MA sub-global assessments; they are not meant to provide definitive or prescriptive definitions.

Science can be defined as systematized knowledge that can be replicated and is validated through a process of academic peer review by an established community of recognized experts in formal research institutions. Scientists use a series of logical and empirical methods of systematic observation in order to understand the world. The scientific method includes making empirical observations, proposing hypotheses to explain those observations, and testing those hypotheses in consistent ways. In essence, scientific methods are impersonal and any one scientist should be able to duplicate what another scientist has done. The validation of experimental results, hypothesis confirmation, and the acceptance of theories by the broader scientific community, through a process of peer review, are viewed as critically important to the maintenance of scientific standards and the quality of research.

Science strives to be objective. However, many philosophers of science argue that all systems of knowledge have embedded assumptions that are socially derived. ''Objectivity is closely bound up with the social aspect of the scientific method, with the fact that science and scientific objectivity do not result from the attempts of individual scientists to be 'objective,' but from the cooperation of many scientists'' (Popper 1950).

Social science disciplines are distinguished from biophysical sciences by the way that problems are articulated, the type of evidence that is used to establish truth or facts, and the way that facts are transmitted, tested, and verified (see, for example, Bryman 2004). Paradigm is a term used to refer to a worldview or conceptual model to which a community of experts within a particular discipline may agree. Adherents to a particular paradigm or discipline organize and interpret observations of the world around them via the constructed knowledge system important to their particular community. All disciplines, whether within the biophysical or social sciences, have their own standards and rules.

Interdisciplinary research projects or assessment processes have to overcome the barriers to understanding that arise when knowledge derived from different processes is exchanged. These barriers may take the form of dismissing the arguments of an unfamiliar discipline, questioning the validity of data analysis, or, more simply, finding it too difficult to work within a foreign construct/worldview because the logic does not make sense (for example, Scoones 1999). Heemskerk et al. (2003) used an innovative approach to bridge disciplines by working in a group in order to produce conceptual models of human ecosystems. These models built on conventions previously established by both ecologists and anthropologists. Through the process of building a model together, the assumptions of each disci-

pline, as well as the points of agreement and disagreement were identified, revealed, and discussed.

According to Abel and Stepp (2003), ecologists and ecosystems managers recognize at least two important roles for social scientists in interdisciplinary teams. One is as ''facilitators'' who can explain culture and social resistance and may permit the easier implementation of environmental policy (Groffman and Pace 1998, cited by Abel and Stepp 2003). Another role is as ''interpreters'' of traditional ecological knowledge that may provide the basis for sustainable ecosystem management and appropriate institutions (McCay and Acheson 1987; Berkes and Folke 1998, cited by Abel and Stepp). Both of these roles are invaluable for what many now agree constitutes sound ecosystem management.

A growing body of research suggests that the study of complex social-ecological systems requires changes in the scientific approach, criteria for truth and quality, and conceptual frameworks. Properties of complex systems include non-linearity, plurality of perspectives, multiplicity of scales, and irreducible uncertainty (Gallopin et al. 2001). ''Post-normal'' science, of which the study of complex systems is a part, involves an examination of human uses and impacts, and issues of value, equity, and social justice (Funtowicz and Ravetz 1993). Hence, post normal science acknowledges uncertainty and lack of predictability as well as a necessary degree of subjectivity in scientific research. Methods associated with post normal science call for participatory approaches in which scientists work with local people or practitioners to close the gap between local/traditional and more formal scientific perspectives and to embrace values and a plurality of perspectives. Much of ''normal'' scientific practice, it is argued, is limited in its ability to handle these elements. Integrated assessments, as the sub-global assessments were designed to be, must deal with complex issues. Wilbanks (personal communication) says that these assessments require a ''sort of softer version of the scientific method: rooted in evidence, analytical approaches, peer reviews, etc., [but also able to accommodate] such things as the treatment of uncertainties, an assurance of balance among stakeholder views, and the possibility of getting the answer wrong.''

Indigenous knowledge is defined as the local knowledge held by indigenous peoples or local knowledge unique to a given culture or society (Warren et al. 1995). In this chapter, the term indigenous knowledge is used only when the sub-global assessments themselves refer specifically to the knowledge held by people who identify themselves as indigenous (for example, Bajo Chirripó and PNG).

Traditional ecological knowledge is a ''cumulative body of knowledge, practice and beliefs, evolving by adaptive processes (i.e., innovation and feed-back learning) and handed down through generations by cultural transmission'' about local ecology (Berkes 1999, p. 8). Traditional ecological knowledge may or may not be indigenous, but has roots firmly in the past. The Four Directions Council of Canada (1996, cited in Oviedo et al. 2000) explains: ''what is 'traditional' about traditional knowledge is not its antiquity, but the way it is acquired and used—the social process of learning and sharing knowledge. This knowledge has a social meaning . . . and varies according to age, gender and other variables.'' Traditional knowledge explicitly includes people, feelings, relationships, and sacredness (Moller et al. 2004).

Local knowledge is the term of choice for some scholars in referring to place-based experiential knowledge. In this chapter, the term local knowledge is used to express knowledge that is largely oral and practice-based in contrast to knowledge that is acquired by formal education or book-learning. Local and traditional ecological knowledge is often relational, in that human qualities are attributed to aspects of the biophysical environment. This belief often engenders a respect for elements in the environment that influence, for example, the timing and the method by which resources are extracted. For example, the harvesting methods and the timing of harvest for yellow cedar and other tree bark in the American Pacific Northwest ensures that the trees stay alive after harvest (Turner 2004).

This chapter uses the term ''local and traditional knowledge'' to describe the full range of knowledge that is encompassed in both definitions. Such knowledge may involve a ''worldview'' that is different from that of scientists and government decision-makers. On the other hand, local and traditional knowledge may, in some cases, incorporate elements of scientific knowledge and vice versa. Clear delimitations of kinds of knowledge are difficult, if not impossible (Agrawal 1995). For example, the PNG assessment found that traditional ecological knowledge is not immune to outside influences, since most coastal communities in Papua New Guinea have been exposed to western schooling and Christian teachings for several generations.

Though a community is considered to hold a certain body of knowledge collectively, information is not distributed evenly, so there is almost always a differentiation of knowledge within a community (Berkes 1999). Certain individuals may be considered the local experts on various parts of the community territory or in various subject areas. Knowledge may be differentiated according to age, status in the community, or specialization. Another critically important aspect of knowledge differentiation is gender. It is well known that women's knowledge can be significantly different from men's knowledge in some areas (Rocheleau et al. 1996). The important implication for research, and specifically for sub-global assessments, is that for the assessment to be valid and legitimate, the study design needs to take into account the issue of knowledge differentiation.

Another group of knowledge holders (and users) critical to the MA are *practitioners,* which includes resource managers, government bureaucrats, decision-makers, and personnel in NGOs, development agencies, and civil society groups. In most sub-global assessments, these are referred to as the assessment users. Although the integration of practitioners' knowledge into research is relatively unstudied, some attention has been paid to the need to understand how practitioners use knowledge for their purposes, whether implementing a development project, making a policy decision, managing a resource, interpreting and implementing a national policy at the local scale, etc. A recent series of studies commissioned by the Overseas Develop-

ment Institute and the Global Development Network through the Bridging Research and Policy Project reached a number of conclusions relevant to the MA work:

- ''Knowledge utilization appears to be almost completely context-dependent,'' so any researchers wishing to influence the policy process would do well to understand the particularities of it (Stone et al. 2001). This context includes the dominant policy narratives, that is, the prevailing wisdom the policy community uses to make policy decisions.
- The policy process is best understood as an interplay among political interests, competing discourses, and the agency of multiple actors (Crewe and Young 2002).
- Researchers wishing to successfully engage with the policy process must consider three factors: context, the type of evidence, and the linkages in place. The second factor, type of evidence, is directly relevant to this chapter, as it pertains to both the quality of the research and the communication and dissemination of research findings to policy-makers. The linkages between research and policy are also relevant in that the legitimacy of the research institution will influence acceptance or utilization of the research in policy-making (Crewe and Young 2002).

Guston (1999) proposed the concept of *boundary organizations,* which are institutions that straddle and mediate the divide between science and policy. Boundary organizations are an alternative to the standard model of the transfer and use of scientific information. Within a boundary organization, ''decision-makers are involved in the creation and maintenance of the relationship with scientists, the science-policy boundary, and the scientific and technical outputs'' (Cash and Moser 2000). The flow of information is multidirectional. Cash and Moser (2000) have also proposed that boundary organizations are useful in multiscale or integrated assessments to bridge various types of knowledge.

The use of these premises illustrating the different kinds of knowledge that may come into play in an assessment raises several issues for discussion. First, involvement of local people and use of local and traditional ecological knowledge in ecosystem assessments such as the MA is important for several reasons: it promotes participatory processes, it enables the creation or unveiling of new knowledge to share across scales, it enables the optimal use of existing knowledge, it aids in the development of indicators of change and resilience to monitor ecosystem dynamics, and it aids in the transformation of existing institutions toward ecosystem management (Gadgil et al. 2003). However, participation alone does not automatically result in multiple benefits for all involved. Allocation of financial, information and decision-making resources so that local resource users have the means to make decisions about access to and use of ecosystem resources is also important (Davidson-Hunt, personal communication). Local and traditional ecological knowledge systems not only provide recognized insights for the qualitative management of resources and ecosystems; some also display several parallels to adaptive management (Berkes et al. 2000; Alcorn et al. 2003). Adaptive management is designed to improve on a trial and error basis, an attribute inherent in the social learning process, where learning occurs at the level of society, not of the individual (Olsson et al. 2004). Berkes et al. (2000) suggest that some traditional ecological knowledge can be described as adaptive because it acknowledges that environmental conditions will always change; it also assumes that nature cannot be controlled and that yields, for example, cannot be predicted.

Second, there is a critical need for well trained, culturally sensitive, interdisciplinary teams who follow an ethical protocol in assessing human–ecosystem interactions, especially when local and traditional ecological knowledge is being used. Expertise in interpreting and working with local and traditional knowledge holders is essential when ecologists are asking questions that may be different from questions asked by local resource users. Anthropologists and others have been researching, documenting, and theorizing on the use of local, traditional, and indigenous knowledge for some time, and the importance of this knowledge in resource management has been discussed in the literature at least since the work of Julian Steward in the 1950s, evolving to the well-recognized field of ecological anthropology, which emerged during the 1960s and 1970s (Steward 1955; Davidson-Hunt and Berkes et al. 2003). Over the last 25 years, the use of local knowledge has become mainstreamed, beginning with the work of D. M. Warren, who made the topic his life's work, and with the publication of *Indigenous Knowledge Systems and Development* (Brokensha et al. 1980). It is important that respect and an ethical protocol are in place when local and traditional knowledge is used in assessments. (See Box 5.1.)

The use of local knowledge by ecological scientists is more recent and the tensions are apparent, both in the MA documents and in the literature (for example, Brosius 2004; Agrawal 2002). There has been a tendency among scientific researchers, as well as among people from outside a given community, not to concern themselves with abstract questions of epistemology or with the nuances of various techniques for gathering information about local and traditional knowledge (Nadasny 1999). This undermines any attempt to bridge local/traditional knowledge with scientific knowledge, and it often places local and traditional knowledge within a scientific framework, granting epistemological privilege to the latter. To move away from the tendency to use local and traditional ecological knowledge only within a scientific framework, steps were taken within some sub-global assessments to ensure that indigenous epistemologies and collaborative approaches themselves set the direction for the assessment.

Involving practitioners' knowledge in an assessment poses the additional challenge of including information on how knowledge is used to develop policy, as well as how practitioners take action to implement a policy or a development project. Knowledge systems are often considered as a tool for decision-makers—they draw knowledge from multiple sources and look to experts to give them pertinent information. Policy processes can be considered opportunities for cross-scale dialogue, although they are often viewed as rather closed processes until something happens which

BOX 5.1

Ethical Protocol for the Use of Local and Traditional Knowledge in Assessments

The ethics involved in working with local communities requires the establishment of, and commitment to, an ethical code of conduct, as well as respect and cross cultural understanding by all members of the assessment team within the communities where the assessment is being conducted. Specifically, the assessment team should consider:

- *Practical issues in establishing the assessment.* Initial assessment set up involves issues of how the assessment is initially received by the communities and whether there is sufficient "buy in" for the assessment to be based in the community(ies) and whether people will be willing to cooperate and collaborate with the assessment team.
- *Trust between community members and the assessment team.* A level of trust is required to assist in the generation of knowledge at the local level, which has implications both for the extent to which knowledge will be shared (Coastal BC) and how interactions with the same communities will proceed (San Pedro de Atacama).
- *Ownership of assessment results.* Ownership of the assessment process and outcomes is enhanced when there is trust and community collaboration in the assessment process. When there is community ownership of results, there is increased potential for capacity-building and empowerment of the communities involved, and a greater likelihood that the assessment results will be used by those communities. Feedback from the community on the results of the assessment is important as well as delivery of assessment results in a format that the community will use.
- *Ethical protocols.* There were ethical protocols established by the MA, stating a requirement for prior informed consent by communities and the requirement for the protection of intellectual property rights. These protocols enhance the practical aspects of conducting the assessment, and provide a foundation for trust between the assessment team and the community(ies) involved. Prior informed consent of knowledge holders is necessary for any use of data or information from a sub-global assessment, and the protocol on IPR states that communities are encouraged to provide information that can be freely shared and to clearly state what information must remain confidential (see MA IPR policies at http://www.millenniumassessment.org/en/about.policies.ip.aspx). There is an obligation on the part of the assessment team to ensure that the communities are aware of the rights that they have over their own knowledge.

Despite the checks that are in place, there remain issues that are not captured in the protocol, and these are widespread issues that occur in most development interventions that involve the use of local and traditional ecological knowledge. For example, it is difficult to make the separation between privately held knowledge and knowledge which is held by the collective community, in addition to a general lack of capacity in communities to ensure that their knowledge is not misused. MA policies and activities related to IPR are designed to help ensure that information concerning ecosystems and their links to human well-being is freely available. Notwithstanding the intent of this free flow of information, the MA sought to develop mechanisms and processes to ensure that the benefits from the application of local/traditional/indigenous knowledge in sub-global and global assessments can be obtained without compromising the rights of the holders of that knowledge.

opens up the possibility for change in the process (Keeley 2001; Blaikie and Soussan 2001). Policy change relies not only on new networks of actors but also on new knowledge to create new discourses on issues.

Third, methods and processes for data collection as well as expression, documentation, and validation of knowledge differ among knowledge systems, and these differences often lead to misunderstandings, rejections, and other forms of conflict between people with different worldviews. For example, science accepts published facts after an elaborate process of validation established by the scientific community. What is of concern is that local and traditional knowledge that is maintained or transmitted via oral, practice-based, and other "tacit" methods may not be regarded as credible within the scientific community, because the expression of local knowledge is often through practice-based procedures, and validation occurs through processes that differ from science. Science-based assessments need to recognize and honor local processes of validation, instead of insisting on validation by the standards of science.

It is a commonly held view that local/traditional and scientific knowledge can be somehow "integrated" and applied to a common purpose. However, the conceptual basis of the endeavor to integrate local/traditional and scientific knowledge has been challenged. Some researchers argue that the very idea of integration (or synthesis) implicitly assumes that knowledge is an intellectual product that can be isolated from its social context (Nadasny 1999). In this chapter, the concept of "bridging" rather than integration or synthesis is useful because it implies that the different types of knowledge retain their integrity but exchange ideas and learn from each other. (See also Chapter 11.) The concept of bridging is also a way to acknowledge that one knowledge system is not superior to the other. The means to achieve bridging is to create dialogue between knowledge systems.

An example of the sensitivity of these issues comes from the indigenous views session at the Bridging Scales and Epistemologies conference in Alexandria, Egypt, in a quotation which questions whether local people would ever be on an equal footing when the two knowledge systems are used together:

> *We can only—consciously—sit down at a table of dialogue, in a world where many worlds (or epistemologies) are welcome, where we can talk between us, and also talk with modern science. But at this table we need to leave behind arrogance and the wish or attitude to dominate. We have to come with humbleness, with eagerness to learn, with openness and respect. In this neutral space of encounter, what can everyone contribute, what is our gift? What is the gift of the scientist? Is the scientist prepared for a dialogue? Is he or she able to support us? Do they have the means to talk with us? Can they enter an alliance*

and commit to overcoming the limitations of their worldviews?

The sub-global assessments reflect the tension in this quote to some extent. In the SAfMA local assessments, local knowledge was considered a vital component of the assessment process, although all local knowledge used was validated by science. India Local is an excellent example of successful bridging, in that students, who themselves were community members, were trained to document local knowledge in collaboration with knowledgeable individuals from the community. This information was then stored in a database at the Centre for Ecological Sciences where it was evaluated by scientific experts. The knowledge was then stored at the National Innovation Foundation where it is safeguarded and where there is value added to both traditional knowledge as well as grassroots innovations in the informal sector. The Vilcanota and Bajo Chirripó assessments enabled communities to assert their knowledge and their understandings of their own environments. In these cases, the communities led the validation process and thus local knowledge was valued in its own right.

Recent work in the field of participatory research for policy change has addressed how local people's concerns can be successfully raised to others (that is, scientists and local officials or higher level decision-makers), but on their own terms. For example, Holland and Blackburn (1998) describe three models for how this can be done: In the most common model, intermediary institutions ''translate'' local voices for the benefit of policy-makers and become activists for local people. In a second model, policy-makers and local people come together directly to discuss issues, and in the third model, intermediary institutions are still active in the translation process, but they pay more attention to ensuring that participation becomes part of the policy process. In a similar vein, some scholars of local knowledge suggest that to provide space for local knowledge, institutions are required that facilitate inclusion without appropriating knowledge (for example, Berkes 1999).

In conclusion, several critical points need to be accepted by any assessment if goals such as those of the MA are to be achieved:

- *the importance of social values (including culture, spiritual, ethnic identity, etc.) and historical context* that are embedded in all types of knowledge, including science;
- *the challenges of addressing complexity and uncertainty.* The interface between society and nature involves complex system dynamics, with multiple causes, feedbacks, and responses. This suggests a high degree of complexity, where a system is difficult or impossible to analyze through the use of a simple disciplinary framework (Munda 2000). Methodological requirements for understanding the complexity of local knowledge include first and foremost methods grounded in the concepts of interaction and connectedness—that local knowledge regarding human–ecosystem relationships cannot be compartmentalized, but must be understood as a myriad of interrelations between the social and biophysical.
- *the significance of institutions, or the rules and practices upon which knowledge interactions are based.* There have been situations in which the voices of particular groups have been suppressed (for example, women, minorities), forcing them to rely on others to articulate their knowledge;
- *the validation of local and traditional knowledge.* In addition to epistemological differences between knowledge traditions, science is often viewed as being privileged or having hegemony over local, traditional, and indigenous knowledge (Scott 1998, p. 323). Satterthwaite (1996) suggests that underlying power relationships are compounded by prejudice resulting from incomprehension of different forms of logic that occur within the institutional context of a project.

5.3 Benefits of Using Multiple Knowledge Systems in an Assessment

Including multiple users in the assessment process is relatively new, but there are several previous experiences upon which the MA can reflect. Integrated assessment involves the participation of ''non-scientists'' on the basis that this involvement will improve the quality of the research, via the input of contextual and practical knowledge, experience, and values. This is especially important for complex and/or unstructured problems, terms that can certainly be applied to the MA. In a survey of the attempts by scientists to include other knowledge in integrated assessments through participatory processes, van Asselt Marjolein and Rijkens-Klomp (2002) praise the intent and acceptance of the principles of participation by assessment teams, but lament the lack of serious analysis of the actual methods and processes used to increase participation and hence the types of knowledge used in assessments.

The MA conceptual framework states that there are certain benefits of using multiple knowledge systems: information benefits, increased participation and empowerment, and broader use and application of assessment findings (MA 2003). This section explores whether these anticipated benefits were realized in the sub-global assessments.

5.3.1 Information Benefits

Several sub-global assessments illustrate how local and traditional ecological knowledge added significant insight to the assessment process (Table 5.1), providing information on locally important resources and management practices, information that is directly relevant to the assessment of ecosystem services. In the India Local assessment, where local knowledge is recognized as complementary to science, a long tradition of reliance on non-wood forest products has resulted in local people's intimate knowledge of native species and their uses, and this information added great value to the assessment of biodiversity. Local knowledge also provided an understanding of the history of surface water use, traditional irrigation and water sharing arrangements, as well as modern developments, including growing demands for water and the associated implications (India Local). In the Sinai assessment, an indigenous Bedouin participant ex-

Table 5.1. Local and Traditional Knowledge (LK) Use by Selected Sub-global Assessments (Data from assessment reports, knowledge markets, and questionnaires)

Sub-global Assessment	Local/Traditional Knowledge Recognized	Approach to Using Knowledge Systems
Tropical Forest Margins	recognized LK composed of process-based knowledge and location-specific knowledge, with the former easier to integrate across scales case study of local ecological knowledge (Indonesia); documentation and policy reform with Krui agroforestry systems (one case)	used different models to incorporate LK long-term presence considered important for obtaining LK liaised with NGOs that work at local level progress in stakeholder negotiations came from developing a shared articulation of the underlying cause-effect relations and the criteria and indicators that can reflect the various concerns
SAfMA	assessment process added value to both formal and informal knowledge, though science dominated process local coping and adaptive strategies important input to assessment	interaction of multiple knowledge systems problematic (introduces uncertainty) but also enriched findings LK was validated only at the local scale by using rigorous PRA and other methods
Coastal BC	mapping cultural-spiritual places provincially mandated land and resource management process provided framework for LK scientific systems favored due to ease of authentication and availability	reluctance to share LK at policy level due to distrust difficulties in bringing LK to an analytical process difficult to use all knowledge systems due to time constraints more time and resources required for locally acceptable modes of investigation
Sweden KW	LK for management practices, species dynamics local agricultural and biodiversity-related knowledge emphasis on social processes underlying successful ecosystem management adaptive co-management builds on institutions and learning and avoids set prescriptions of management superimposed on a particular context	mutual learning through interviews with stakeholders strong linking through networks of steward associations links made between conservation and development were considered important
San Pedro de Atacama	active collaboration with LK holders public and private knowledge used LK provided more nuanced understanding of local conditions not found on maps and data important to validate assessment processes and findings	Indigenous Law (1991) affirmed LK, however LK was not incorporated properly in the water management sector Mining Foundation promotes community development through social health and education projects the local museum, open to the public, disseminates information about local culture
PNG	robust cultural traditions, not subsumed under scientific framework rich body of LK relating to the many kinds of spiritual beings that inhabit local ecosystems close collaboration with local communities	prospects of compensation for communities distort merging of scientific and local perspectives scientific assessment of the drivers challenged by the local community as a distortion or violation of LK, because the practice of "science" was identified with the activities and claims of a private sector environmental monitoring program
Downstream Mekong	local perspective used to strengthen assessment all information was validated by local communities specific LK on medicinal plants used	consensus-driven linkage via workshops, dialogues poverty and low education impeded cross-scale understanding at local level
Eastern Himalayas	local level indigenous technologies shared among villages	links made between villages and between scientists, local government, and local resource users
India Local	mapping used to integrate LK and science assessment built on traditional forestry management practices Community Biodiversity Registers (CBRs)—compilations of LK on medicinal plants	the people working in the assessment were locals (not outsiders), which facilitated links embedded in a national effort to use LK science taken to local level: computer techniques taught to local students

	local perceptions of soil and water provided insights: history of surface water use, traditional irrigation and water sharing arrangements, modern developments (i.e., implications of increasing demands for water) sacred conservation practices documented but very heterogeneous and difficult to map used five local languages and two scripts	LK (because it is largely derived through a trial and error process, commingled with beliefs) posed great difficulties for validation
Sinai	LK was the most dominant knowledge system in assessment medicinal plant knowledge, and knowledge of water scarcity, was stressed; gender recognized as a sociocultural factor determining variations in biodiversity management; government recognizes tribal law	Bedouin associations supported in efforts to affirm the cultural transmission of knowledge conflicts in knowledge interaction due to concerns for intellectual property rights LK considered essential for higher-scale water management
Laguna Lake Basin	both local and scientific, but scientific knowledge was dominant LK only based on literature review—no data	no direct work with LK holders conflicts with the state over traditional tenure system
Portugal	local-level knowledge (incl. practices) in the case study of Sistelo practical management knowledge from users in government, industry, agriculture, and NGOs	integrated participatory methods used some conflicts between local users and the state due to appropriation of community forests
Altai-Sayan	traditional land use patterns of local communities; environmental consciousness based on religious beliefs	religious-based environmental consciousness of rural people was used to address issues on a larger scale to generate environmental awareness for conservation
Bajo Chirripó	LK provided direction for assessment, conceptual framework, and needs assessment adaptation of the MA framework was based on stories and histories from the elders about the habitat, its creation, and the norms that regulate its use, complemented by scientific literature review a first interpretation of the relation of ecosystems and human well-being was from the indigenous Cabecar perspective information validated in community gatherings convened by elders in other Cabecar communities	to be applicable, the MA framework needed to describe ecosystem services and human well-being more integrally, as the local perspective does
Vilcanota	LK given equal footing with scientific knowledge (SK) both LK and SK used to assess conditions and trends, adaptation of conceptual framework, traditional practices, local people cross-checked science entire process undertaken with community approval (local validation) problems defined by the communities knowledge mostly related to agroecosystems, also ecosystem interactions (broader definition of ecosystems that incorporates spiritual elements)	knowledge interactions were key to the assessment how to work with multiple knowledge systems not fully worked out yet, but to be performed by the technical team in consultation with local technicians and reviewed by community groups
Argentine Pampas	scientific knowledge dominated the assessment regional knowledge from farmers' groups traditional technical knowledge from retired agronomists and farmers corporate cultural knowledge from agri-business and governmental agents	no strong linkage between agents and decision-makers who operate at different scales and manage different scale-dependent knowledge conflicting interests and knowledge approaches to management among farmers, agri-business, and governmental agents workshops (driven by scientists) helpful to foster mutual understanding between stakeholders that represent conflicting knowledge systems
Wisconsin	LK used for scenario development	

plained the reasons behind the increase in some of the invasive species that were not known in the region previously, which was considered an important driver of change at the local level. In the Kristianstad Wetlands assessment, local knowledge provided historical continuity with information covering time periods that scientific studies have not covered (Sweden KW).

In the Altai-Sayan ecoregion, more than 20 different indigenous ethnic groups have lived together for centuries. The assessment reported that protection of Altai-Sayan biodiversity ultimately depends on the ability of the local communities to preserve their traditional land use practices. For example, in Mongolia people have, over millennia, developed a specific traditional approach to the use of grazing areas, which includes the formation of a particular species ratio composition of livestock (a combination of camels, horses, cattle, goats, and sheep). The specific percentage of each species in the livestock herds leads to the most uniform grazing of the whole range of grazing plant species. This practice maximizes the efficiency of the use of pasture areas. However, for the past decade, new, young herders who are not experienced in nomadic herding, along with weakening state control of grazing activities, is leading to unsustainable herding practices (Altai-Sayan).

Many local assessments found that local and traditional ecological knowledge had particular insights for human well-being. For example, in the Sinai, local knowledge is important for crisis mitigation practices. The Bedouin have a particular cropping system, based on growing a variety of crops, in order to reduce the risk of crop failures as a result of drought, a common occurrence in Sinai. Very often crops are selected so that the presence of one protects the other from pest infestation. For example, cantaloupe is grown beside *Artemisia judica,* a species that helps the cantaloupe set fruit and reduces insect infestations. Another example in Sinai is that in times of political conflicts and war, when people are cut off with no access to regular health care, they rely on their knowledge of local herbs to provide them with treatment for various diseases and illnesses. In the communities involved in the India Local and San Pedro de Atacama assessments, traditional healers are still highly valued for their knowledge of the different medicinal and nutritional properties of plants. In the India Local assessment, however, the popularity of medicinal plants is a factor leading to their decline.

In the Eastern Himalayas assessment, local knowledge used to be important to well-being in terms of ensuring livelihood security, such as rural handicraft production and food production. The SAfMA Livelihoods assessment found that local people also rely on diverse local knowledge for sustaining their livelihoods and managing risks. For example, they exploit resources over time and space and value multiple landscapes and mobility. They change labor strategies depending upon rainfall, and they use different microenvironments for agriculture, grazing, collection of wild fruits, etc. Resource and species substitution is a common adaptive strategy. In the case of water, which is a vital but scarce resource, people protect it with cultural taboos as well as management practices (SAfMA Livelihoods).

Some assessments such as Eastern Himalayas, found that communities no longer have the benefit of local or traditional ecological knowledge contributing to human well-being, due to socioecological changes, economic changes, and the loss of local and traditional knowledge. Many assessments reported that local knowledge systems were threatened or hard to articulate, because they have been so eroded. (See Box 5.2.)

Some sub-global assessments also gave examples of how local and traditional ecological knowledge deals with change, which is critical in terms of information benefits for assessments, since it is an indicator of the resilience of communities and ecosystems. In India Local, for example, local and traditional ecological knowledge bases forecasts of ecosystem productivity on bioclimatic indicators. This knowledge blends historical perceptions of crisis manage-

BOX 5.2

State–Local Interactions and Their Impact on the Transmission and Validity of Local Knowledge: South Africa

Resource patches imbued with sacred qualities according to traditional knowledge have played a well-documented role in the conservation of key ecosystem goods and services important to rural South African communities. However, a history of state intervention in the management of natural resources in South Africa has resulted in the erosion of the importance attached to "sacredness" in many instances. In South Africa, this process has been linked strongly to apartheid ideologies and policies on the one hand and to global and national trends toward scientific agriculture on the other. More recently, basic service provision has had unintended but equally important impacts on the perceived validity and importance of traditional knowledge.

Traditionally, among the isiXhosa people, local ecological knowledge developed through an adaptive process of learning by doing, and was transmitted orally between generations through story-telling, folklore, and ritual. However, state intervention in education and agriculture between the 1960s and 1990s severely undermined local confidence in indigenous knowledge and belief systems. Scientific farming practices, for example, were enforced through local rangers and state extension officers at the expense of locally developed farming practices. At the same time, the legitimacy of traditional leadership, which was linked to local and traditional belief systems, was systematically undermined by a series of policies and interventions that effectively lead to a general disillusionment with traditional leadership.

More recently, the nationwide drive to reduce inequitable access to basic services has had important, albeit unanticipated, impacts on the validity and therefore transmission of local knowledge. The provision of reticulated water in rural villages has drastically decreased local dependence on natural water sources, and therefore elders have in many cases ceased transmitting knowledge regarding sacred pools. As a result, many youngsters have begun to water their livestock in these pools, reducing vegetative cover and threatening sensitive species that were formally protected by the traditional belief systems. Similarly, traditionally protected fuelwood species reserved for ritual purposes alone, have, since the political collapse of the ranger system in the early 1990s, decreased dramatically. Fuelwood collectors, often young women, are often no longer aware of traditional taboos formerly placed on certain species and harvesting techniques.

ment with philosophy, which can provide useful precautionary principles. However, despite this potential, local and traditional ecological knowledge is not used to manage ecological crises at present. This area requires more research into the potential contribution of local and traditional knowledge since the norm is to rely on scientific models of changes such as climatic events, soil fertility decline, and pollution from various sources.

The inclusion of knowledge held or used by practitioners, such as municipal officials, was possible in the MA process either through the inclusion of practitioners in the assessment team (for example, Sweden KW) or, as was more commonly the case, through user forums. (See Chapter 6.) In the sub-global assessment user forums, practitioner knowledge was expressed according to the ''role'' of the practitioner in the management of the area under assessment or their ''need'' for information from the assessment. However, the Kristianstad Wetlands assessment reviewed all participant knowledge according to whether it was ecological, used for management, or pertained to social processes. The wetlands ecosystem has been managed through an integrated process for almost 15 years, and all groups acquire new knowledge and learn from one another through the design of the management process.

The Coastal British Columbia assessment provides an interesting insight into the use of practitioner knowledge in the assessment. The need for independent information precipitated the establishment of an independent, multidisciplinary information body and a transparent peer review process that would provide the best available information and expertise to support the development of an ecosystem-based management approach to natural resource management and planning. The team consisted of independent scientists, practitioners, and traditional and local experts, overseen by a management committee and supported by a secretariat. The five-person management committee consisted of representatives of the founding partners (the provincial government, First Nations, environmental NGOs, forest products companies) and the community at large, and was co-chaired by provincial government and First Nations representatives. In this case, ''technical'' knowledge held by assessment users was seen as too subjective and possibly biased if it was too closely aligned to particular sectoral interests, for example the timber industry. The independent nature of the information gathering process was considered important to this assessment (Coastal BC).

The Tropical Forest Margins assessment was heavily invested in a process of stakeholder engagement (strategic stakeholder analysis) in order to understand the needs and perspectives of multiple users at local, national, and international levels. While this work is on-going, the following quote offers a rare insight into the barriers that must be bridged:

> *Initial findings from the efforts to contrast ''local,'' ''public/policy'' and ''scientists/modelers'' ecological knowledge suggest that further analysis can help in reducing conflict and finding practical solutions. Local ecological knowledge on watershed functions is ''process-based'' and well-articulated for observable phenomena such as overland flow, erosion, sedimentation and filter effects. It does not depend on strict ''land use categories.'' By contrast, public or policy ''knowledge'' is based on such categories and the attributes that are supposed to go along with ''forest'' and ''non-forest'' land cover. Science can potentially bridge between ''process'' and ''pattern'' based understanding and can usefully interact in both arenas. Progress in actual stakeholder negotiations can come from developing a shared articulation of the underlying cause-effect relations and the criteria and indicators that can reflect the various concerns. Breaking through existing categories at the policy level, and especially recognizing the ''intermediate'' systems and forest mosaics as the focus of interest in natural resource management requires a change to ''evidence-based'' discourse. (Tropical Forest Margins, p. 14)*

Within the MA multiscale assessment design, local assessments were conducted at finer scales to provide information for the most appropriate levels for policy, decision-making, and action. Implicit in the inclusion of sub-global assessments was the need to link knowledge systems across scales (and hence power and decision-making levels), with a particular emphasis on social and ecological knowledge at the local level. The information benefits can only be realized if there is full participation of local/indigenous peoples both in the assessment process itself and in using the assessment findings. Other resource and assessment users also need to be brought in, so that conflicts or synergies among either knowledge or information needs can be discussed and resolved. The second benefit of the use of multiple knowledge systems, participation, is discussed in the following section.

5.3.2 Participation as a Means to Empowerment for Local Resource Users

It is generally acknowledged that care must be taken to ensure that participation is done thoughtfully and in a collaborative manner. Many practitioners of participatory rural appraisal methods acknowledge that there is a problem in using these tools as part of a routine set of exercises, instead of as the basis for real engagement, which is usually a time-consuming process (for example, Cleaver 2001; Mosse 1998). Full, collaborative participation is not easy to achieve and there are often inherent problems of treating participation superficially. Even though the mechanics of participation are built into the assessment process, effective involvement of all stakeholders often requires training in facilitation and always requires respect and an ethical protocol (Chambers 1997). In addition, partnerships are necessary for effective participation, requiring reciprocity and humility (Berkes 1999).

Others point out that participation without resource allocation can be meaningless and unfair (Paci; Davidson-Hunt, personal communication). For example, participation requires peoples' time, it tends to raise the expectations of the local participants for resource allocation, and it requires that research information and results are fed back into the community for their verification and use as well as appropriate follow up action (Narayan et al. 2000). The inclu-

sion of both resource and assessment users also raises the distinct possibility of conflicts of interests, information needs, and the knowledge or evidence that is held to be credible, relevant, and legitimate.

Experts on participatory research such as Chambers (1997) point to differences in levels of participation. Such differences can have profound implications for assessment outcomes. Table 5.2 describes the roles and influence of different knowledge groups (or participants) in the sub-global assessments. A difficult category to analyze is that of assessment user, as this group included a wide range of knowledge holders. Not every assessment made clear whether the resource users were in a decision-making capacity (San Pedro de Atacama), were collaborators in the assessment (as in Vilcanota, Bajo Chirripó, or BC Coastal), or were merely consulted for their knowledge as input into the assessment (SAfMA).

In the Bajo Chirripó assessment, all participation was collaborative. Local indigenous people were involved in assessment design, and they changed the direction and focus of the assessment. The communities decided that instead of developing a new resource management plan, they would focus on recovering lost knowledge that in the past safeguarded the integrity of the environment and ensured the sustainability of human activities. (See Box 5.3.) In the Vilcanota assessment, the indigenous Quechua groups had a key role in the problem identification process as well as the assessment of ecosystem services, indicating collaboration in the early critical stages of the assessment that will likely influence the outcome.

Table 5.2. Participants and Their Roles in Selected Sub-global Assessments (Information from knowledge markets and questionnaires)

Sub-global Assessment	Knowledge Group/Participant Category	Role in Assessment Process	Influence in the Assessment Process
Bajo Chirripó	community members	team members and users	directed the assessment objectives and framework
	biologist	team member	managed the work process
Vilcanota	international expert on indigenous issues	initiated assessment	let community control process
	"barefoot" (local) technicians	part of team and also users	facilitated work with community because they possess LK but also understand the scientific framework
Sweden KW	local resource user organizations	team members and users	contributed ecological and management knowledge
	administrative officials	team members and users	contributed ecological and management knowledge
Tropical Forest Margins	scientists (interdisciplinary team)	team members	have led research process from initiation; set priorities for product delivery
	policy-makers	assessment users	helped with problem identification and contributed knowledge
Western China	scientists	team members	managed assessment process
	politicians	team members and assessment users	assisted with scenario development
Coastal BC	scientists	team members	contributed knowledge to assessment
	government officials	team members and users	initiated assessment and provided information to analysis
	private sector	team members and users	initiated assessment, contributed information
	First Nations	team members and users	initiated assessment, contributed knowledge, gathered data
San Pedro de Atacama	indigenous community members	assessment users	contributed local knowledge to all parts of the assessment
	NGO in charge of assessment	assessment team	directed and managed the assessment process
	government officials	assessment users	contributed knowledge and expressed information needs
India Local	local community members	assessment users	contributed knowledge
	educational institutes	assessment team	facilitated process with communities
	scientists	assessment team	contributed scientific knowledge and validated local knowledge
	policy-makers	assessment users	provided enabling policy environment for assessments to be institutionalized nationally

BOX 5.3

Adaptation of Traditional Ecological Knowledge for Resource Management: Bajo Chirripó

Asociación Ixacavaa de Desarrollo y Información Indígena began the Bajo Chirripó assessment with the idea of developing a management plan for the community's resources. Through discussions and meetings with community members, it soon became apparent that in the past, a strict "management plan" had existed and was based on norms and beliefs regarding interactions between humans and their environment. The concept of reciprocity was key (between humans and the rest of the environment).

IXACAVAA therefore changed the focus of the assessment from developing a management plan to recovering lost knowledge that in the past safeguarded the integrity of the environment and ensured the sustainability of human activities. A conical shaped house represents the natural world. The flip side (also a conical house) is the spirit world and is equally important. Communities have noticed a big decline in the number of animals and the quantity of important natural resources available to them in their territory. They explain this by saying that the animals have left the natural world and are hiding in the spirit world (the upside down cone). When humans begin to act more responsibly with great reciprocity, the animals will return to the natural world (conical house). Because of the discussion of these ideas within the process of the assessment, community members in one village decided to build a conical house (which can also be physically constructed on earth and becomes a spiritual icon to the communities), which has now been completed.

In San Pedro de Atacama, the Atacameño indigenous peoples, along with several representatives of local mining companies, were members of the advisory committee; they helped to identify the focus of the assessment and offered feedback throughout the assessment process. However, the assessment team offered the following comment, which illustrates the difficulties of full participation when multiple stakeholders do not trust one another or the assessment process:

> *Mining companies have information on monitoring and studies on the situation in the Salar basin that they had not shared with locals (prior to this assessment), and locals hold knowledge about the landscape they are not prepared to share for fear it will be used against their interests. This is the main pitfall that research projects in the area have to face. To counteract this, the project has encouraged a policy of transparency and access to the information it has generated, but it has been difficult to achieve the participation of the wise men and women from the communities after past experience with other initiatives that were not totally open about their scope and objectives. A workshop with local leaders to discuss their views and possible future scenarios took one step towards overcoming this distrust. (San Pedro de Atacama)*

Local users of these three assessments had different levels of ownership over the assessment process. The capacity to influence the process in significant ways, through collaboration, contributed to the acceptance of the usefulness of the exercise in the cases of Bajo Chirripó and Vilcanota. None of the sub-global assessments were able to report (at the time of writing) on how the assessment users will ultimately use the assessment findings or benefit from the assessment experience in the future. Potential benefits may include access to assessment findings that are relevant to their political agendas, and access to MA tools and networks of communication with which they could draw attention to their causes. In the case of assessments where local and traditional ecological knowledge was used in the assessment of ecosystems and human well-being, the holders of that knowledge may be empowered by the recognition of the value of their knowledge at the national or international level.

In other assessments, it is less clear whether ''participation'' in the assessment process was consultative or collaborative in nature. Chapter 9, which assesses the responses in the sub-global assessments, emphasizes that collaboration (multisector and multi-level) is important for the best, integrated responses. The framework used in Chapter 9 lists knowledge systems as one of four features of any response, suggesting that the bridging of knowledge systems is crucial for collaborative responses.

Since knowledge and values are both situational and time-linked (Colson 1984, cited by Borofsky 1994), taking knowledge out of context is almost inevitable when knowledge systems are bridged through increased participation. When elders or other specialized knowledge holders in the community are consulted, their contribution is often confined within an established scientific framework and their vast repertoire of past experiences and what motivated them are not considered in their operative context. For example, the complex of personal relationships and the spiritual beliefs that influence how people interact within their environment may be largely overlooked in the quest to find fact-based local knowledge that is valued for environmental management. The indigenous, local or traditional knowledge that is accessible to outsiders is often confined to present day realities of secular life, information on scarce resources, and features of ecosystem change, based on long-term observation. Therefore, members of the assessment team must understand the nature of knowledge that is context-dependent and be able to interpret non-factual knowledge as well.

Table 5.3 shows that the assessments used a variety of participatory methods. In the Vilcanota and San Pedro de Atacama assessments, NGOs were the initiators of the participatory processes. However, in San Pedro de Atacama, the NGO was located outside the community and was largely composed of scientists, which may have made their role as a ''mediator'' awkward. NGOs may function as boundary organizations between local and traditional ecological knowledge and practitioners and scientists; however, they may also define the parameters for the use of local/traditional knowledge, rather than the communities doing this themselves (S. Gauntlett, personal communication). The experiences of the MA sub-global assessments in general have shown that there are often important trade-offs between developing meaningful local participation in assessments and progressing with the assessment work within a fixed time frame and within a prescribed budget. The

Table 5.3. Methods Used to Incorporate Multiple Knowledge Systems in Selected Sub-global Assessments (Information from knowledge markets and questionnaires). KI = key informant.

Sub-global Assessment	Methods Used					Who Initiated
	KI	Workshops	Household Visits	Community Meetings	Other	
Western China				+		local governor
	+					local scientists
					other participatory tools	secretariat of Western China assessment team
			+			local scientists
India Local	+				mapping, resource inventories, questionnaires, validation methods	scientists
SAfMA					collection of "tacit" knowledge through collation, evaluation, summarization, synthesis, dialectic and communication; other methods: focus groups, forum theater, story lines, cross validation, and triangulation	scientists
Sweden KW				+		EKV scientists
	+					scientists from Stockholm University
					literature reviews, including vegetation surveys and land use maps; also social-ecological inventories	EKV staff and scientists from Stockholm University
San Pedro de Atacama				+		communities, via Indigenous Development Area policy initiative
	+	+		+	Advisory Committee meetings, theater, participant observation	RIDES (Recursos e Investigación para el Desarrollo Sustentable)
Wisconsin				+	scenarios, computer games, web survey, and randomized mail survey of public responses to scenarios	assessment team
Coastal BC	+					assessment team
		+				planning tables
					literature review	assessment team
					GIS	governments, First Nations, private sector
					statistics	federal and provincial governments
					modeling	biophysical scientists
					surveys (phone, mail)	assessment team

Vilcanota assessment recognized that user engagement and the development of an assessment process by indigenous communities would take a long time; the MA Secretariat (with Board approval) set aside funds for over a year while waiting for a proposal from the Vilcanota assessment team, knowing that the process would eventually contribute information about how to advance the use of local/traditional ecological knowledge in sub-global assessments.

In summary, the MA recognized that assessments may become extractive processes, whereby particular elements of local/traditional ecological knowledge are taken out of their cultural context and used within a scientific framework. This use of local/traditional ecological knowledge may assist the research process, but it is much less clear how local users benefit from the assessment, even when it relies on their knowledge. The question that needs to be asked in every assessment is whether the information is appropriated or obtained through a transparent collaborative process, in which knowledge holders are fully aware of their rights to confidentiality. Once local and traditional ecological

knowledge is documented, there is the question of legitimacy, validation, and credibility, and who sets the standards for comparison (discussed further in the next section).

5.3.3 Use and Application of Findings

The need to be ''relevant, credible, and legitimate'' to assessment users was the main reason the MA initially decided to incorporate multiple knowledge systems. For example, the MA global Responses report recognizes that in order to assess the social and ecological impacts of a particular response, policy-makers must recognize the existence of a range of worldviews and acknowledge that the adoption of a specific policy response may privilege specific worldviews (MA *Policy Responses,* Chapter 2). This requires that knowledge holders be meaningfully engaged assessment users in order for results to be relevant, credible, and legitimate to them. This is reason to explore just how effectively the voices of local farmers, fishers, indigenous peoples, and businesses are able to contribute to the assessment process as ''users'' and how they may actually influence policy.

Chapter 6 of this volume shows that, in many cases, the initial ideas for sub-global assessments came from individuals linked to the global MA process. In general, scientists, rather than decision-makers or communities, initiated the assessment process. This suggests that relevance for scientists was established from the outset in most cases, while relevance for other users required dialogue and varied from assessment to assessment. Coastal BC was an exception, as the assessment was part on an on-going process of policy development that was requested by a coalition of users, rather than initiated by scientists. The Sweden KW and India Local assessments were embedded in ongoing management and policy innovations, so although local participation played a significant role, this may have been a product of an on-going process rather than driven by the assessment itself. There are often challenges for making externally driven processes relevant to local resource users, as they must respond to an idea generated outside the community. The imposition of ''grassroots'' processes generated from demand at higher levels is problematic because ownership is confused and contested (for example, Baumann 2000). User engagement was generally better in assessments with higher levels of meaningful resource user participation (for example, directing the research process) and where potential users saw the assessment process as something they needed. (See Chapter 6.)

Most sub-global assessment users were members of national, regional, or district governments that develop policy outside the community level. (See Chapter 6.) This raises the question of when local people are actually assessment ''users,'' since local people cannot ''use'' the assessment if they do not have broad-based decision-making power. In many cases, where decision-making power resides largely outside the community, community members are only ''consulted'', and their knowledge is extracted for the purposes of other ''users.'' However, the literature indicates that when assessment results are made available and accessible, local people will often make use of the results (for example, Berkes 1999; Alcorn et al. 2003). Although local people may not be able to influence higher-level decisions, they do make day-to-day decisions about resource management, and assessment results may be useful in this context. In addition, numerous local institutions are gaining increased authority over local resources as a result of decentralization processes; these local institutions may be able to use and benefit from the assessment results, although this is not an automatic process. Recent studies (for example, Narayan et al. 2000; Ellis and Freeman 2002; SLSA 2003) emphasize that local institutions often do not respond effectively to the needs or objectives of the poor.

Most sub-global assessments report that including local and traditional ecological knowledge and other non-scientific knowledge improved the credibility and relevance of their processes and outputs to certain users. For example, the India Local assessment addressed the information needs of the Panchayat (local) level of government, which, after the passing of the Biodiversity Act of India in 2002, gained direct control over resources such as ''minor forest products.'' In Bajo Chirripó, non-scientist participation, which focused on knowledge held by the communities, both strengthened that knowledge and increased the relevance of the assessment to the communities. The international community (including the Swedish International Biodiversity Programme) has noted the usefulness and innovative qualities of the approach being taken by the local NGO, Asociación Ixacavaa de Desarrollo y Información Indígena, and has responded by providing funding for the project. According to the assessment, ''the community members working as technicians seem to be empowered by the process, which attaches credibility to the traditional knowledge of their people'' (Bajo Chirripó).

Finally, the SAfMA Garongosa-Marromeu assessment reported that involving local resource users potentially increased the relevance and credibility of the findings; however, the utility of local/traditional knowledge can also be downgraded by the local community itself, as indicted by the comment that ''it is strange [that] in some communities we work with, they themselves downgrade their own knowledge, wanting outside 'scientific' information because it is seen as being better'' (T. Lynam, personal communication). This comment points to a long history of the power of dominant paradigms and how that may affect bridging knowledge systems.

There are more complex questions to ask as well. If the assessment users are at the national or global level, how can local and traditional ecological knowledge be seen as a credible information source? What about ethics: Was the process extractive? Are the local knowledge holders aware of the implications, in term of intellectual property rights, of sharing their knowledge with users at other scales? Similarly, if the assessment users are at the local level (as in India Local), how was capacity developed to enable local people to develop and implement policy? For example, did the assess-

ment process help or was a different institutional or policy intervention required?

The Coastal BC assessment reported that it relied too heavily on science for two reasons: (1) technical information was viewed as too closely tied to sectoral or other interest groups, and (2) bridging First Nations' knowledge took more time and resources than anticipated. The San Pedro de Atacama assessment commented that traditional knowledge does not hold the same validity as scientific knowledge for decision-makers, who prefer to stick to the predominant scientific codes sustaining government policy. Therefore, it is a challenge to generate mechanisms that allow local and traditional ecological knowledge to be incorporated into the decision-making process in a similar way to scientific knowledge (San Pedro de Atacama). This sentiment has been echoed by others involved with participatory poverty assessments (for example, Schoonmaker-Freudenberger 1998), which underscores the importance of well-designed participatory processes.

A related point is that decision-makers often want access to local knowledge on their own terms (S. Gauntlett, personal communication). Traditional weaving and carving among the Maori in New Zealand provides an example; the traditional patterns of this highly sought after art form are being copied (often without consent) by outsiders who are not concerned about the cosmology that surrounds the importance of the weavings. In accessing the design without the surrounding belief systems, the outsiders are inherently changing the knowledge systems that the artifacts are part of and this will over time affect the designs themselves. In a similar way, Nadasny (1999) argues that often decision-makers co-opt knowledge.

Assessing the credibility, legitimacy, and relevance of information for decision-makers involves difficult questions of politics and power. A model for assessing the complexity that is introduced by acknowledging the influence of political power over the knowledge that is accepted by assessment users is described by Pritchard and Sanderson (2002). Integrated assessments themselves deal with complex and inherently uncertain issues, but the reality is that alternative but equally viable models of resource dynamics exist, which means that different interest groups or political bodies can choose models to support arguments that serve their own purposes. Pritchard and Sanderson point to this as the essence of so-called ''wicked'' problems, which involve a host of academic and social perspectives that cannot be separated from issues of values, equity, and social justice; that are relevant to multiple arenas of action; and that are difficult for anyone to solve.

Few assessments comment explicitly on conflicting information, and indeed a full discussion of it is beyond the scope of this chapter. However, the Tropical Forest Margins assessment team plans to explore how to ''articulate participation across multiple groups with conflicting interests,'' because they work with both local and national user groups, which have different knowledge, and because their problem domain, land use at tropical forest margins, involves numerous trade-offs and conflicting interests.

5.4 Design and Process for Incorporating Multiple Knowledge Systems

5.4.1 MA Design: Guidelines for the Use of Multiple Knowledge Systems in Sub-global Assessments

The challenge of incorporating multiple systems of knowledge was not explicitly recognized by the exploratory steering committee that designed the basic MA structure in 1998–99. However, the committee did take the decision to include sub-global assessments within the MA structure and to include a broad array of stakeholders on the Board governing the assessment process; these decisions, in turn, led to a growing focus on the issue of knowledge systems during the technical design phase in 2001 and during the initial meetings of the MA Board.

From a practical standpoint, the decision to include sub-global assessments, and particularly local assessments, within the MA process required that the MA modify the procedures used by the Intergovernmental Panel on Climate Change (which were otherwise generally adopted for use by the MA) to enable the use of knowledge and information not published in the scientific literature. The IPCC procedures had already provided a mechanism to incorporate ''gray literature'' into that process, largely in response to concerns expressed by the private sector that the first two rounds of the IPCC were not taking full advantage of materials published by the private sector that were not available in scientific publications.

Other international forums have also addressed the need to include other sources of information and knowledge, for example the International Council for Science Series on Science for Sustainable Development. During the second technical design workshop of the MA in October 2001, the sub-global assessment ''breakout'' group developed a process and set of protocols for validating unpublished information, with a particular focus on local or community assessments. This process of validation was further refined at the first Sub-global Working Group meeting in June 2002 and the resulting mechanism was then incorporated into the MA procedures. The elements of these policies concerning the practices that would be used in working with different knowledge systems are presented in Appendix 5.1 of this chapter.

The array of proposed sub-global assessments involved in the MA during the design phase in 2001 were largely derived from a ''call for proposals'' circulated in September 2000. (See Chapter 6.) Because this initial call for proposals was circulated primarily through government, scientific, conservation NGO, and development NGO networks, the set of proposed sub-global assessments involved did not span a particularly broad range of knowledge systems. Even among the MA local assessments, most were initiated by scientists external to the communities involved. The technical design workshops in 2001 and the first meeting of the Sub-global Working Group in 2002 both encouraged the incorporation of a broader array of sub-global assessments. This was also encouraged by the MA Board, which in-

cluded individuals from indigenous communities, local assessments, and the private sector, all of whom argued for additional assessments to be established within the communities or sectors that they represented.

Efforts to expand the array of sub-global assessments to include assessments that involved using multiple knowledge systems were not particularly successful, however. Building on MA Board contacts, an effort was made during 2001 to stimulate the establishment of several additional assessments led by indigenous peoples. This involved the circulation of the sub-global assessment concept paper through several relevant NGO networks, discussions with interested individuals, and a small brainstorming session with indigenous participants at a meeting of the Convention on Biological Diversity's Subsidiary Body for Scientific, Technical and Technological Advice. Although interest was expressed in the idea, particularly by indigenous peoples involved in the CBD, no new assessments were generated through this effort. Similar steps were taken to generate ''private sector'' MA sub-global assessments and these steps also did not yield any new assessments. Despite the initial receptivity among these groups to the idea of launching new assessments, some of the likely factors that contributed to their ultimate reluctance to enter into the process included:

- the benefits of undertaking the MA sub-global assessments were not as clear to these stakeholders as they were to governments and scientists;
- the basic approach of the assessment was not something that either the private sector or indigenous communities were familiar with;
- some of the skills needed to undertake such an assessment were absent; and,
- particularly for indigenous communities, the inability of the MA to fully fund an assessment may have posed an insurmountable hurdle.

The elaboration of guidelines and methods for addressing multiple knowledge systems in the MA was undertaken in parallel with the process of launching both the global and sub-global assessments. By the time the product of the design phase, the conceptual framework, was published in late 2003, the MA was committed to including sub-global assessments and different knowledge systems. For example, the MA conceptual framework (2003) states:

- . . . The management and policy options available and the concerns of stakeholders differ greatly across these scales. The priority areas for biodiversity conservation in a country defined by ''global'' value, for example, would be very different from those defined by the value to local communities. The multiscale assessment framework developed for the MA provides a new approach for analyzing policy options at all scales—from local communities to international conventions.
- Traditional societies have nurtured and refined systems of knowledge of direct value to those societies but also of considerable value to assessments undertaken at regional and global scales. This information often is unknown to science and can be an expression of other relationships between society and nature in general and of sustainable ways of managing natural resources in particular. To be credible and useful to decision-makers, all sources of information, whether scientific, traditional, or practitioner knowledge, must be critically assessed and validated as part of the assessment process through procedures relevant to the form of knowledge.

Despite these statements of intent, the sub-global assessments struggled with the methodologies for incorporating multiple knowledge systems. The first pilot assessment conducted as part of the MA, an assessment in the Mala Village cluster in India Local, provided an early approach and methodology for conducting assessments across knowledge systems. This methodology was made available to the participants in the MA design meetings in 2001 and a presentation on the approach was made as well as copies of the approach distributed during the first meeting of the Sub-global Working Group in 2002. In general, working group meetings provided an opportunity for the sub-global assessment coordinators to learn from the methods used in the other assessments, but since the sub-global assessment teams had sometimes already made key decisions regarding the methods and design of individual sub-global assessments, they could not always fully incorporate these lessons.

The MA conceptual framework makes explicit mention of the assessments as a social process to bring the findings of science to bear on the needs of decision-makers. Reid (2004) discusses the provisions made within the MA for the inclusion of local knowledge. These provisions deal primarily with documenting and establishing the validity of non-scientific, particularly local, knowledge. They include taking self-critical notes of the assessment process, triangulating methods to test results, ensuring that the community has the opportunity to review the assessment process and findings, and review by stakeholders at higher and lower scales. Making the connection from policy statements to implementation is important because lack of guidance in how to articulate local and traditional ecological knowledge so that it is understood by all assessment users, as well as overcoming inherent mistrust and misunderstanding, hampered some sub-global assessments (as it has many other assessments and participatory projects).

The question remains as to how an indigenous group can become part of the authorizing environment when the assessment is to be ''scientific.'' Who decides what is ''belief'' and what is ''fact''? This is not an issue specific to the MA, but rather part of the wider debate on the epistemological basis of science (M. Nadkarni, personal communication). In most places where sub-global assessments were conducted, policy-related decisions are not made at the local level, so it is not clear how assessing local knowledge and including it in the overall assessment can lead to empowerment and more appropriate decision-making, two goals the MA strives for (discussed later in this chapter).

5.4.2 The MA Process: Incorporating Multiple Knowledge Systems

The MA has explicitly recognized that to achieve conservation and sustainable use of ecosystems, traditional and formal knowledge systems need to be linked and that the

influence of intangible benefits, such as spiritual and religious values, on sustainable natural resource management at the landscape level needs to be strengthened. (See MA *Current State and Trends,* Chapter 18.) Limitations and shortcomings of integrating non-formal knowledge and formal science need to be addressed up front, and the methods that are chosen to collect this knowledge should take the location-specific environments in which they operate into account (Singhal 2000). Research suggests that if traditional ecological knowledge is to be integrated with other forms of knowledge, it must be understood within its historical, socioeconomic, political, environmental, and cultural context (Berkes 1999).

As discussed in the previous section, the MA design was modified to allow the inclusion of ''non-scientific'' information in the body of knowledge being used to assess ecosystem services and human well-being. The MA Secretariat did not itself develop methods to ''bridge'' knowledge systems, as such an endeavor was regarded as beyond the scope of the project. The design of the MA largely relied on encouraging sub-global assessments to independently test methodologies for the incorporation of local and traditional ecological knowledge into scientific assessments within their own local, national, or regional context. The MA did provide a forum for the presentation and possible further development of methodologies to advance the understanding of bridging knowledge systems at the conference in Alexandria, Egypt. The MA process and working group meetings provided a forum for discussion for the sub-global assessments, within which ideas, methods and approaches to the treatment of different forms of knowledge were shared. At early meetings, a large amount of time was often spent on the topic of local/traditional/indigenous knowledge. The discussions highlighted the importance of incorporating different forms of knowledge, particularly the challenges associated with doing this. There appears to have been little attention devoted to understanding how knowledge is used in decision-making processes.

The Bridging Scales and Epistemologies conference highlighted the fact that guidance on the use of participatory methods was lacking in the sub-global assessments. One problem was that methods needed to be designed to fit the specific context of each assessment and hiring an outside consultant to advise sub-global assessments on how to adapt their process might be considered inappropriate. In the case of Vilcanota, the process is still proceeding slowly at the time of writing this volume, but control of the assessment and development of methodologies will ultimately reside with the communities involved in the assessment. The process must be allowed to develop in its own time; for this reason, it may be some time before it can be truly understood what advances the sub-global assessments have made in this field.

Most often, local and traditional ecological knowledge is explored by interdisciplinary teams, because multiple perspectives strengthen results and the interdisciplinary approach is a backbone of the entire field of participatory research. An important consideration is the fact that, overall, the MA process emphasized ecological science more than the social sciences. This has been to the detriment of the inclusion and full understanding of the potential that local and traditional ecological knowledge can make to an assessment. In many sub-global assessments, several different scientific disciplines were represented in the assessment team. There were almost always ecologists, often economists, but rarely people with long experience working with local knowledge, such as anthropologists, philosophers of science, or community-oriented researchers and development practitioners. (See Table 5.4.) Only a few assessments, such as SAfMA, Tropical Forest Margins, and Portugal, discussed how the different disciplines in the assessment teams shared knowledge or influenced the outcomes.

The Tropical Forest Margins assessment offers rich insights into achieving integration among knowledge systems. As part of their MA activities, 42 members of the assessment team participated in an online consultation on how the program has managed the goal of integrated research (Tomich et al. 2004). The results of this consultation pointed to the time and dedication that working across disciplines and interests requires, although all of the team highly valued the interdisciplinary approach and considered it essential to answering key questions. Essential to the success and longevity (10 years) of this team was commitment to a common set of research issues and shared analytical protocols, yet enough flexibility and free exchange so that new ideas could be incorporated and prior assumptions or hypotheses could be rejected. The team was assisted by the constant presence of a coordination office, which acted as a bridge between scientists and users.

The Portugal assessment, which involved 35 scientists from the natural and social sciences, provides some insight into interdisciplinary integration as well, with the recognition of ''technical and stakes'' gaps (Pereira et al. 2005). These gaps illustrate the differences in both disciplines and interests of scientists. Due to the complexity of social-ecological systems, there is a lack of scientific knowledge to predict how these systems will evolve, and scientists disagree on the future trajectory for particular social-ecological systems. These gaps were bridged somewhat during the development of scenarios and the qualitative assessment of conditions and trends. In the scenario work, the creative process of developing descriptive narratives allowed for better communication between the different scientists.

SAfMA used a ''trans-disciplinary'' approach, as the assessment team held the view that working across disciplines is indispensable when dealing with complex multiscale systems (Cundill et al. 2004). Due to limited resources, the approach involved a trade-off between the ability to include and recognize the influence of a multitude of factors and the development of an in-depth understanding of the linkages among all identified processes. The SAfMA team also had to struggle with interdisciplinary dialogues and competing explanations of events by different scientists, which made consensus difficult.

In-depth understanding of local knowledge by outsiders requires skill, training, respectful behavior, an open and non-judgmental attitude, and experience of place within an

Table 5.4. Contributions of Various Knowledge Systems to Selected Sub-global Assessments (Information from questionnaires)

	Knowledge Systems Contributing to Assessment						
Sub-global Assessment	**Ecologists, Botanists, Zoologists**	**Other Biophysical and Natural Scientists**	**Anthropologists and Sociologists**	**Economists**	**Other Socioeconomic Scientists**	**Practitioners**	**Boundary Organizations**
San Pedro de Atacama	designed and executed the assessment process; dissemination of findings		provided context and understanding of indigenous practices and traditions	designed and executed the assessment process; dissemination of findings			public sector agencies assisted with development of accurate scenarios
Coastal BC	team leaders and members for ecosystem spatial analysis, ecosystem trends, risk analysis, ecosystem-based management	geographers, foresters, mining geologists contributed to assessment; team members for ecosystem-based management, spatial analysis, and well-being assessment	team leader and members for cultural and spatial analysis, and for well-being assessment	team leaders and members of economic analysis; members of ecosystem-based management team	political scientists and lawyers contributed to, and are team leaders and members of, policy and institutional analysis; members of ecosystem-based management team		managers of overall assessment; team leaders of ecosystem-based management and well-being assessment
Sweden KW	information on species diversity, population changes, habitats, monitoring of rare species					EKV staff were part of the technical team that helped in problem identification, condition and trends and response options development	
Tropical Forest Margins	biodiversity index that enabled analysis of trade-offs with other disciplines	carbon sequestration; agronomic sustainability	insight into nonquantifiable institutional/social variables	economic profitability of land use systems		NGOs	
Portugal	conducted most of the assessment	forest and agricultural engineers assisted in conducting most of the assessment	one anthropologist involved in the socioeconomic analysis of the assessment	conducted economic evaluation of ecosystem services	social scientist collaborated with ecologist to conduct Sistelo community assessment		representatives of the public and corporate sector helped shape the assessment questions
SAfMA	primary source of knowledge for assessment; validator of local knowledge		implemented and interpreted participatory methods/results	developed socioeconomic profiles		NGO	

interdisciplinary team (Chambers 1994, 1997). It should be noted that some hold the view that only indigenous people themselves should be the ones to investigate indigenous knowledge, stemming from a belief that all knowledge is politicized (Smith 1999).

The assessment technical teams differed greatly in terms of expertise and experience. While some teams were able to progress rapidly with the general assessment work, others struggled with the design of the basic assessment. Few teams were able to work effectively with local/traditional/indigenous knowledge, due to lack of expertise, although three quarters (25 out of 34 assessments) tried to some extent. By sharing experiences, methodologies, and lessons learned, the teams with less experience in this kind of work were exposed to ideas on how to go about working with other kinds of knowledge. For example, the expert in participatory methods from SAfMA spent several months working with both the Vilcanota and the San Pedro de Atacama assessments, training them in methods of working with local knowledge holders. Assessments run by teams primarily composed of biophysical scientists were encouraged to widen their perspectives on their assessment areas, inhabitants, and sources of information. Ultimately, however, individual assessment teams, along with their advisory committees, decided to what degree they would work with local and traditional ecological knowledge systems in the context of their own assessments.

One indication of the limited experience that the sub-global assessments had in using multiple knowledge systems is that gender differentiation of local and traditional knowledge was not considered in the MA even though it is almost always recognized as critical in the study of human–ecosystem interactions (for example, FAO Sustainable Dimensions 2001). Assessment reports did not discuss the importance of understanding gender differences in knowledge, except for the Sinai assessment. As mentioned earlier, local and traditional ecological knowledge is also differentiated by age, wealth, and status in the community, all of which need to be considered in the assessments that rely on local/traditional ecological knowledge. Several assessments (for example, San Pedro de Atacama and Sinai) did note that the community elders were the primary holders of traditional knowledge.

Understanding the social, cultural, and economic context of place requires a historical analysis of trends and evolution not only of knowledge (for example, recent discoveries), but also of the use of this knowledge over time and space in different institutions. Few sub-global assessments gave much treatment to the historical context in which current knowledge use is based. San Pedro de Atacama and Eastern Himalayas both discussed economic changes in the past decade as negatively affecting local knowledge, although in San Pedro de Atacama recent political and legislative changes are encouraging a renewed interest in indigenous identity, for cultural and economic reasons. In contrast, India Local embedded the assessment in the national historical context, but did not discuss local knowledge within this.

SAfMA reports that participatory rural appraisal tools were useful for discussing local and traditional knowledge at the local scale, but in order to make it meaningful at higher scales, the knowledge had to be re-articulated so that scientists and others could relate to it. This often takes local and traditional knowledge out of its context and thus changes it. SAfMA relied on cross-validation, which puts local and scientific knowledge on an even plane, so that local experts validate scientific knowledge, and scientists validate local knowledge. In this way, as the assessment authors assert, the integrity of local knowledge can never be ''guaranteed'' by scientific standards, but by using the various techniques in a complementary way, a form of ''local peer review'' is introduced that greatly enhances the credibility of local and traditional knowledge from the perspective of scientific users (Fabricius et al. 2004).

A process is on-going in India Local, where validation of local knowledge is a concern for national policy development. Validation is done by collating local knowledge, storing it in the People's Biodiversity Register, and then transmitting it to the National Institute of Innovation, in English. In Vilcanota, two different databases were used—one in Quechua and one in Spanish—to be able to get the information to central decision-makers. In San Pedro de Atacama, biophysical scientists did not take concrete steps to exchange information and generate synergies with those with local knowledge; local knowledge was not used in the assessment for various reasons. Therefore, the challenge is to call upon scientists from all disciplines involved to develop bridges and exchange mechanisms for knowledge sharing. It will be similarly important to find institutions and decision-makers willing to share knowledge across levels as well. In this case, as well as in Vilcanota, Sinai, and Bajo Chirripó, the assessment itself can be viewed as an important first step in building awareness of the need for and benefits of bridging local knowledge with higher scale decision-making processes.

Several assessments incorporated the knowledge of assessment users (practitioners), such as government bureaucrats or local NGO workers. In the case of India Local, the involvement, support, and participation of local government (Panchayat) officials was encouraged, given their direct control over natural resource access and management at the local level; school teachers and students were responsible for the collection of local knowledge. In Sweden KW, all stakeholders were classified according to the knowledge they have, from farmers up to municipal officials. The Sweden KW framework considered that every user group has a type of basic ecological knowledge, as all stakeholders are considered to use the ecosystem services in some way. Many stakeholders have knowledge about technology and are skilled in management practices. The rarest form of knowledge, regarding the social processes behind ecosystem management, is held only by the Ecomuseum Kristianstads Vattenrike, which is the mediating institution that coordinates the social networks that collectively manage the wetlands (Sweden KW).

5.4.3 The Influence of Different Knowledge Systems

This section examines how the involvement of different scientists and a range of non-scientists influenced the assessment processes and outcomes. The intent is to explore the depth of contributions that non-scientific knowledge holders were able to make. Table 5.1 above summarizes how all the sub-global assessments viewed and used local knowledge, and the approach that different sub-global assessments took in using local and traditional knowledge systems. Note that much of the information was verbally transmitted during the knowledge market during MA Sub-global Working Group meeting held in Alexandria, Egypt, in March 2004.

Several assessments attempted to recognize the complexity of local and traditional ecological knowledge. For example, seven assessments (Coastal BC, PNG, India Local, Sinai, Bajo Chirripó, SAfMA, and Vilcanota) investigated and helped to articulate the spiritual component of local knowledge, which is important in understanding what motivates particular behavior in human–ecosystem interactions. In PNG, for example, local ecosystems are imbued with spiritual beings, an understanding of which lent insight into the patterns of resource use. In another example, in the sacred groves in India, the assessment drew upon the conservation benefits of the spiritual values associated with certain forest areas. The reworking of the conceptual framework by the Quechua community of Vilcanota, Peru, and the Cabécar in Bajo Chirripó, Costa Rica, relied heavily on spiritual components of local and traditional ecological knowledge.

A number of sub-global assessments pointed out the importance of local knowledge to cultural identity; examples include the Bedouin of the Sinai, the Atacameños in San Pedro de Atacama, the Quechua communities in Vilcanota, the Cabécar of Bajo Chirripó, and the Haida Gwaii and the north and central coast First Nations of Coastal BC. Transmission of traditional knowledge is currently having the positive effect of affirming the Atacameño culture and identity in San Pedro de Atacama and of strengthening community cohesion in Vilcanota; in both these cases, however, the need for continued support of policy-makers is important. As several researchers have noted, failure to grasp and acknowledge these deeper or more complex aspects of local knowledge, robs this knowledge of some of its inherent meaning.

Most sub-global assessments, on some level, depended upon local knowledge to complement science. For example, Western China and India Local highlight the important observations and innovations local and traditional ecological knowledge contains for soil and water conservation. SAfMA highlights the rich diversity of management practices and coping strategies (which contain observations about complex use of landscapes) based on local knowledge. The Mekong Wetlands, Viet Nam, assessment highlights the tremendous value of local knowledge of medicinal plants.

In three assessments, the concept of integrating local knowledge with science was rejected: PNG, Sinai, and, to some extent, Coastal BC. Local communities in Papua New Guinea see no need for science, because their local knowledge systems are so robust and form the basis of their daily practice. Similarly, in Sinai, the Bedouin rely heavily on their own knowledge for their livelihood needs, but fear both cultural erosion and knowledge appropriation.

In Coastal BC, local and traditional knowledge was not used along with science for a number of reasons. The assessment team used all four of the recognized knowledge systems (scientific, technical, traditional, and local) to some extent. However, the timetable imposed on the assessment, the ready availability of scientists, the relative ease with which their qualifications could be authenticated, and their apparent independence, favored the use of scientific systems. In contrast, indigenous (First Nations) knowledge systems posed certain challenges: (1) the information on First Nations' traditional territory will be used politically (to support their position in treaty negotiations) and some First Nations think they will put their case at risk if they reveal the information in advance; (2) some information on spiritual sites or sites closely associated with the identity of a clan or household is highly sensitive and must not be made public; (3) some information is not available to the First Nation as a whole but is owned by particular clans or families; and (4) time is required to observe rules of behavior, negotiate with the owners of information, and grasp different worldviews and classifications—time that was not available to the assessment. The authors of the assessment stated that there was not enough time or resources to devote to incorporating traditional knowledge. With hindsight (and the passage of time), they realize that they could have made better use of indigenous and other local knowledge, particularly in the assessment of provisioning/cultural services. Specifically, they could have developed expert-based indicators on the biological and cultural diversity of food systems and the status of contributing ecosystems and species, using estimates from First Nation and other local experts as well as scientists (Coastal BC).

Six assessments achieved some form of two-way or cross-scale interactions between science and local and traditional ecological knowledge: SAfMA, San Pedro de Atacama, India Local, Sweden KW, Vilcanota, and Bajo Chirripó. SAfMA, after validating and re-interpreting local knowledge, returned some of this knowledge, along with the scientific results, back to the communities, using theater and scenarios. The methods involved in scenario development in some sub-global assessments resulted in cross-scale (both vertical and horizontal) knowledge sharing as well as bridging knowledge among multiple stakeholders, including scientists, practitioners and local/traditional knowledge holders. In SAfMA, scenarios developed at a national, regional, and basin level were presented to the community as storylines, so that the community could relate to them. The outcome was that local people were able to envision taking control of their own future as a plausible scenario. In San Pedro de Atacama, scenarios were used with the advisory group, which was composed of multiple stakeholders. The outcome was trust-building and the realization that all stakeholders need to be involved in an assessment to determine what responses should be prioritized as follow up to

the assessment. The scenarios helped both these communities to better understand the reasons for participating in assessment processes.

In India Local, local/traditional ecological knowledge was not viewed as an alternative to science, but rather as an integral part of ecosystem understanding, as only local resource users have in-depth knowledge about local biodiversity and resources. The assessment was embedded in a larger effort to acknowledge and use local knowledge, but there remain difficulties in validating some types of local knowledge and its use at a higher level is as yet untested. In Sweden KW, the distinctions between local and scientific knowledge were not presented as distinctively as in India Local, but the whole evolution of the EKV represents a multiscale and multi-knowledge holder effort to combine information for the best ecosystem understanding and management. So far, this appears to be a very successful dialogue.

In Vilcanota and Bajo Chirripó, science deferred to the local indigenous knowledge base. Both sub-global assessments spent a lot of time working with the communities to validate and reinterpret the MA conceptual framework and the science behind it in order to enhance the relevance of the MA to local communities. Science was seen important to complement and strengthen local knowledge, as well as to help address ecosystem crises that are new to the region and unfamiliar to local resource managers.

In contrast, in several assessments, no local knowledge was used. The Caribbean Sea assessment acknowledged that large organizations external to the region have more influence regionally than the countries in the region, which widens the gap between local level realities and global perceptions (KM–Caribbean Sea). In Laguna Lake Basin, only scientists participated in a review of information from secondary sources, thus current local level knowledge did not inform the assessment.

Approaches to using multiple knowledge systems also varied within assessments. Not all local assessments could use both local knowledge and science together. In Eastern Himalayas, local knowledge is scarce. In Coastal BC, local people were reluctant to share some aspects of their knowledge with outsiders. In Downstream Mekong, differences in educational and income levels impeded mutual understanding between local stakeholders and the assessment team. In Sinai, outsiders recognized the richness of Bedouin local knowledge of water harvesting and medicinal plants; however, the Bedouin are protective of this knowledge, as it is integral to their cultural identity. The SAfMA assessment incorporated local knowledge predominantly from a natural resource management perspective, and the use of these management frameworks improved the legitimacy and validity of the assessment. The process, however, was less participatory than that advocated by the proponents of community-based natural resource management (Fabricius et al. 2004) and less legitimate than a bottom up assessment in the eyes of the local people.

Table 5.2 highlights the differing influences of participants' knowledge systems on both process and outcome. From the materials available, we cannot with confidence explain how processes and outcomes were influenced by different participants. However, it is evident in several assessments that the influence of scientists and policy-makers in the assessment process and outcomes was greater than that of local and indigenous communities. For example, in Northern Range, SAfMA, Western China, Tropical Forest Margins, and Caribbean Sea, the assessment processes were defined by the teams of scientists. The San Pedro de Atacama assessment predominantly relied on science, only selectively involving local ecological knowledge, but the assessment validated the knowledge and devoted attention and resources to understanding it and reporting on it. In several assessments, science was used where local knowledge may have been more informative. For example, in Argentine Pampas, a sociologist translated the link between human well-being and ecosystem services and a government consultant was hired to consider outcomes.

Thus most assessments used local knowledge as an information source that science validated and reinterpreted for other assessment users. As of this writing, not many sub-global assessments have reached the stage of developing policy-relevant messages, which is consistent with the lack of evidence from the sub-global assessments on how to create policy–research dialogues or policy–local resource user dialogues.

5.4.4 The Utility of the MA Conceptual Framework for the Assessments

Given the complexity of local knowledge, and the issues involved in using multiple knowledge systems, the utility of the MA conceptual framework for the local sub-global assessments is important to consider. The framework represents the worldviews of scientists and some assessment users, but while it proved useful to most of the sub-global assessments, there are lessons to be learned from those where it was not found to be an effective tool for assessing human–ecosystem interactions in the local context.

In SAfMA, researchers found the conceptual framework of the MA to be insufficient to deal with dynamic local interactions, and therefore difficult to use as a starting point with the communities. To overcome this challenge, the SAfMA local-level assessments combined the adaptive renewal model (Holling 1986; Berkes and Folke 1998; Gunderson and Holling 2002) with the MA framework as a conceptual guide. This model regards social and ecological systems as intrinsically linked and posits that micro-level phenomena can affect macro-level processes as much as the macro affects the local. The model also acknowledges the adaptive capabilities of local communities and ecosystems, an aspect significantly lacking in the MA framework that was crucial for the SAfMA assessment. The sustainable livelihoods framework (Ellis 2000; www.livelihoods.org) was also used to accommodate these adaptive strategies.

In Bajo Chirripó, the basic concepts of the MA conceptual framework were understood to some extent but it was nevertheless quite foreign to community members' way of thinking. Recognizing a need to understand these concepts in the language and from the perspective of the community,

the assessment team and the Cabécar community together invested considerable time in revising the conceptual framework. A full local framework has not yet been completed/developed for this assessment, but components have been identified and discussed in the community.

In Vilcanota, the adaptation of the MA conceptual framework constituted an important part of the assessment work. (See Box 5.4.) The assessment team found that the English terms used in the framework were difficult to translate into Quechua. In addition, the diagram itself and the terms used in the conceptual framework were difficult for the community to relate to, based on their own experience of the environment. The ANDES technical team realized that to move forward with the assessment and for the communities to take ownership of the process and results, the framework would have to be based on a Quechua worldview, and not on the MA worldview, translated for their use.

The Coastal BC assessment adapted the MA conceptual framework to emphasize key relationships. The essential structure of the MA conceptual framework was unchanged except for the addition of human interactions that directly link human drivers and ecosystem services. These links reflect the key role of competition and conflict among users of ecosystem services in determining who benefits from which services and how much they benefit. A separate box in the diagram was added to Ecosystem Condition to highlight the need to maintain ecosystem integrity in order to maintain the supply of ecosystem services. Drivers were separated into ''human'' and ''ecosystem'' drivers in recognition of the distinct differences between them. Human drivers were reduced to three major groups: populations, needs and wants, and powers (such as technology, money, knowledge, access, and rights) that fuel competition and conflict among the users of ecosystem services and amplify the combined impact on the ecosystem of populations and their needs and desires. Direct and indirect drivers were merged, except for the ways in which human drivers act on the ecosystem (identified in the human impacts box). Drivers were reduced to two major groups: conversion of ecosystems (to structures and cultivation) and use of ecosystem services, which emphasized that the use of ecosystem services strongly affects ecosystem condition and hence the supply of services.

Three assessments (Sweden KW, SAfMA, and Wisconsin) used the concepts and theories of *resilience* (Gunderson and Holling 2002) and *adaptive co-management* (Olsson et al. 2004) as part of their conceptual frameworks. Sweden KW also prioritized the idea of social-ecological systems (Berkes and Folke 1998) and highlighted the role of flexible institutions and matching management practices, social processes, and ecosystem processes at various scales. (See Chapter 11.) In the Northern Highlands Lake District, Wisconsin, assessment, the MA conceptual framework volume (MA 2003) appeared too late to be used explicitly in the assessment; the framework, however, was considered useful to assessment organizers, but too technical for local users. The assessment used complexity theory to deal with the problems of unpredictability of ecological forecasts, which contributed to determining indicators of social–ecological resilience that could be drawn upon for sustainable development in the area. (See Box 5.5.)

Several assessments had few problems, if any, in using the MA conceptual framework. In Western China, where the framework was also used for three other projects, it was easily understood by local scientists but required some explanation to decision-makers. The framework was used to design a questionnaire targeted at local farmers and other community members. The San Pedro de Atacama assessment used the conceptual framework despite some initial problems for some user groups that necessitated some innovation, such as changing the meaning of words (for example, instead of conditions and trends, the assessment team use the word ''baselines'' to refer to the current situation) and introducing the conceptual framework gradually. This made it more comprehensible and less complex, and thus promoted the involvement of all users. Finally, in the Sinai assessment, the conceptual framework was used, but it was mostly understood by those with formal academic training, such as government officials working in the assessment area. However, the assessment team noted that the local Bedouins appreciated the way the framework examined connections between a good environment and a good quality of life.

5.4.5 Knowledge Systems, Institutions, and Scale

An initial MA hypothesis was that knowledge is embedded as well as privileged at specific levels. Just as the MA concerns itself with linking biophysical and social data across scales, a treatment of knowledge systems and the institutional structures that support and use them, and how knowledge and institutions interact across scales, is in order. (See Chapter 11.) Institutions are defined broadly as the rules of the game devised as constraints for shaping human action (Ostrom et al. 1994; Young 2002)

A question to be examined is whether the sub-global assessments shed light on which type of knowledge predominates in management at different scales. It appears that science is the knowledge system legitimized at national and regional scales and used as the primary source of information in most assessments, including SAfMA, Western China, Eastern Himalayas, San Pedro de Atacama, and Tropical Forest Margins. While most community assessments reported that local knowledge is very important at local levels, it is more difficult to determine whether local knowledge is legitimized as a basis for decision-making at other levels, without more information on the institutional contexts that support decisions. (See Table 5.5 for details on the relationship between knowledge systems and scale.)

A number of assessments described local or community institutions as essential for the maintenance of local knowledge. SAfMA, for example, highlights the role of social networks and rituals in maintaining and transmitting knowledge that is important for survival. However, these institutions are weak, having been considerably influenced by a history of state interference and deliberate erosion of local knowledge and customs. Stewards associations and craft associations are also important at the local scale. In

BOX 5.4

Constructing a Conceptual Framework for Quechua Communities: Vilcanota

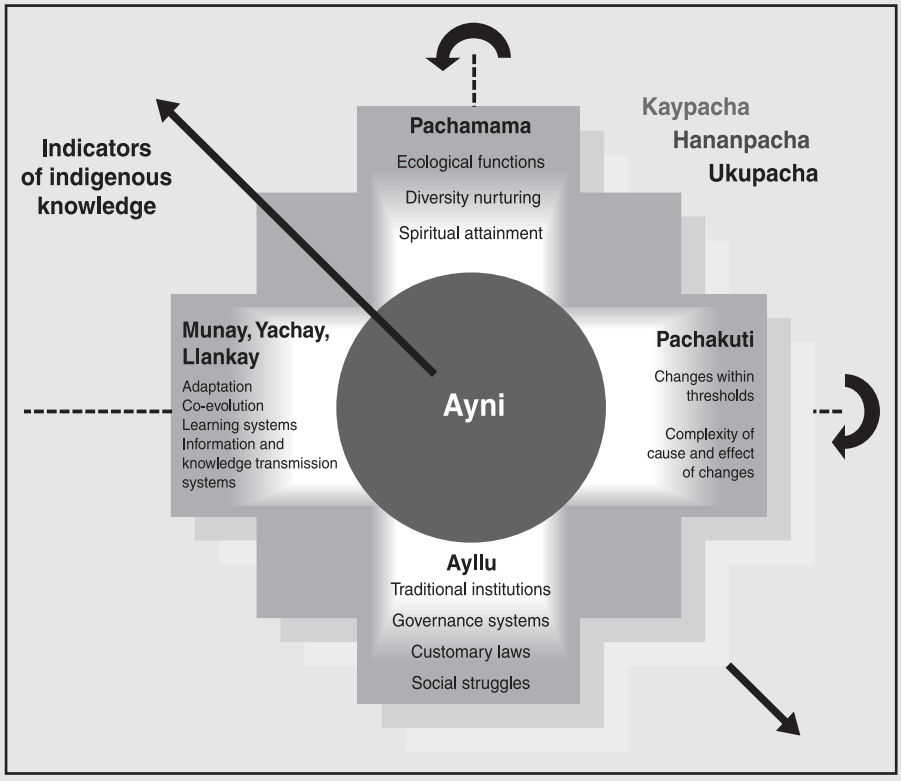
The Vilcanota assessment team initially planned to adapt the MA conceptual framework to be more easily understood by Quechua communities in Vilcanota. However, initial consultations with several Quechua communities suggested that in order to establish dialogue between the MA concepts and the Quechua communities, the team needed a framework built up from the Quechua understanding of ecological and social relationships.

The team began with the Quechua cosmovision, represented in an ancient Inca icon that embodies the Andean conception of ecosystems. This view can be interpreted to include most modern "scientific" notions of ecosystem functioning, but has several key distinctions. Concepts such as reciprocity (*Ayni*), the inseparability of space and time, and the cyclical nature of all processes (*Pachakuti*) are important components of the Inca definition of ecosystems. Love (*Munay*) and working (*Llankay*) bring humans to a higher state of knowledge (*Yachay*) about their surroundings, and are therefore key concepts linking Quechua communities to the natural world. *Ayllu* represents the governing institutions that regulate interactions among all living beings. These and other key components were then compared with key components of the MA conceptual framework in order to determine which needed to be included in the local conceptual framework for the Vilcanota assessment. The resulting framework has many similarities with the MA framework, but the divergent features are considered to be important to the Quechua people conducting the assessment (see figure).

The Vilcanota conceptual framework includes multiple scales (*Kaypacha, Hananpacha, Ukupacha*), which represent both spatial scales and the cyclical relationship between the past, present, and future. Inherent in this concept of space and time is the adaptive capacity of the Quechua people, who welcome change and have become resilient to it through an adaptive learning process (although it is recognized that current rates of change may prove challenging to the adaptive capacities of the communities).

The Southern Cross shape of the framework diagram represents the *Chakana,* the most recognized and sacred shape to Quechua people and orders the world through deliberative and collective decision-making that emphasizes reciprocity (*Ayni*). *Pachamama* is similar to ecosystem services combined with human well-being. Pachakuti is similar to the MA "drivers" (both direct and indirect). *Ayllu, Munay, Yachay,* and *Llankay* may be seen as responses, and are more organically integrated into the cyclic process of change and adaptation.

The MA's four categories of ecosystem services had to be augmented by one: Quechua working groups could not include the service of "protection" offered by the *Pachamama*—a broader vision of an ecosystem, described as "mother earth, major divinity, place where past, present and future coincide, a living system embodying humans and all living beings (including lakes, rocks, mountains, the sky etc), nurtures and cares for all"—in the four MA categories.



PNG, Bajo Chirripó, and Vilcanota, ritual and spiritual beliefs help to maintain and validate local knowledge. The Bedouins of the Sinai protect their knowledge by maintaining a strong cultural identity, and they are reluctant to share their knowledge with outsiders. In Sweden KW, India Local, and San Pedro de Atacama, the transmission of local and traditional ecological knowledge is supported by the education system. In PNG and Sinai, the practice of storytelling and intergenerational transmission are still viable ways to maintain local knowledge, while in San Pedro de Atacama (as elsewhere) elders no longer transmit their knowledge to younger generations in such a regular fashion. Experiential learning has long been a mechanism by which local and traditional ecological knowledge evolves,

BOX 5.5

Complexity in Scenario Development: Wisconsin

The future of the Northern Highlands Lake District of Wisconsin is uncertain. For that reason, the assessment team decided that conventional scientific tools were inadequate for conservation planning, since these methods do not take into account *uncertainty, contingency,* and *reflexivity* (Carpenter 2002, cited in Peterson et al. 2003). For example, when the *uncertainty* of forecasts is rigorously evaluated it is usually found that the prediction is uncertain, meaning that it assigns roughly equal probability to a wide range of extremely different outcomes. Ecological predictions are *contingent* on drivers that are difficult to predict, such as human behavior. The *reflexivity* of human behavior further constrains the possibility of ecological predictions (Funtowicz and Ravetz 1993)—if predictions are made and taken seriously, people will change their actions in response to the predictions, making accurate forecasts difficult (Carpenter et al. 1999).

In the assessment, a scenario planning approach was adopted to take into account the problem of prediction and to deal with model limitations and uncontrollable, irreducible uncertainties in a structured way so as to create management plans for sustainable development. The assessment involved a series of workshops to determine who the key actors are in the district, the key ecological services the district provides, the district's history, the key social–ecological linkages, and the external drivers that may affect the district. In doing so, the assessment identified critical processes that are important, uncertain, and difficult to control and worked to identify key components of resilience and possible actions to assure that the system remains resilient.

and transmission of local and traditional knowledge is strongly dependent on its practice (Ingold 2000). In places where traditional practices still support livelihoods and access to the resource base is assured, practice-based knowledge thrives.

When institutions change (as when rules governing access to resources change or when changes in economic conditions result in the disuse of certain resources), local and traditional knowledge may be eroded or lost. In San Pedro de Atacama and the Eastern Himalayas, the decline in the economic significance of traditional agriculture and crafts has led to the abandonment of some local and traditional knowledge. However, indigenous knowledge is dynamic—as some knowledge and practices are lost, other kinds of knowledge and practices are elaborated (Berkes 1999). In San Pedro de Atacama, efforts are under way to link indigenous culture and knowledge to the tourism industry. The indigenous population, represented by the Consejo de Pueblos Atacameños (Atacameño People's Council), is undergoing a process to recover and affirm its identity, which includes the expression of cultural and spiritual values connected to the ecosystem. Indigenous people are looking to develop a leading role in the growing tourism industry by infusing these particular cultural features into tourism activities (ethnotourism and agrotourism).

Discussion of decision-making and empowerment of local people requires not just including their knowledge, but also dealing with local and community institutions regarding the acquisition, treatment, and transmission of knowledge. For local communities to participate in decision-making at higher levels of political organization, these knowledge institutions need to be functional, either recreated or newly established. The Sweden KW and India Local assessments were embedded in institutional structures designed to enable interactions among knowledge held at different scales (and with different amounts of power). The India Local assessment evolved both in response to a perceived lack of interaction between science and local knowledge (Gadgil et al. 2003) and the changing policy structure that enabled natural resource management and use of local knowledge at the local level (Gokhale and Gadgil 2004). In Richtersveld National Park, the importance of local people in conservation was recognized by ensuring protected use rights (SAfMA). In San Pedro de Atacama, national laws were passed to protect indigenous rights, but implementation at the local level involves new, nontraditional institutions reaching out to local communities; the assessment team chose to work at the local level because of local people's distrust of local institutions. The Vilcanota and Bajo Chirripó assessments attempted to create space to begin a dialogue between local communities and higher level decision-makers.

The success of each of these efforts can only be evaluated with more time. However, in the three assessments most committed to ensuring that local knowledge is heard at higher levels (India Local, Vilcanota, and Bajo Chirripó), key community members who have also been trained in the scientific worldview were important for the bridging of knowledge systems.

5.5 Lessons Learned: Incorporating Multiple Knowledge Systems in Future Assessments

Many sub-global assessments demonstrated a real will and desire to engage with local and traditional knowledge holders and other non-scientist assessment users. Most assessment teams were multidisciplinary and involved multiple stakeholders. The analysis in this chapter focused more on the use of local and traditional knowledge than on the synergies and conflicts among various disciplines and stakeholders.

The sub-global assessments that used local and traditional ecological knowledge reported on the utility of such knowledge for assessment. Most importantly, the assessments stressed the value of this knowledge for the daily livelihood practices and strategies of most local resource users. However, the outcomes of these efforts to include more than just scientific knowledge varied greatly according to:

- the level of effective participation of local users and their role in decision-making;
- the development of capacity in local institutions to work with local and traditional knowledge;
- the strength or intactness of local and traditional knowledge systems;
- the interest and will on the part of local communities and other assessment users;

Table 5.5. Institutions, Scale, and Knowledge Systems in Selected Sub-global Assessments (Information from assessment reports)

Sub-global Assessment	Knowledge Systems Used in Assessment	Scale at which Institution that Uses the Knowledge Operates	Interaction of Knowledge Systems across Different Scales
Sweden KW	combined and collaborative (science, decision-maker, and local resource user)	cross-scale: EKV (along with social networks) local scale: recent initiatives for learning in schools; stewards associations	the EKV documents interpreted local knowledge for higher scales, and enables local management by connecting to these higher-level decision-makers stewards associations enabled horizontal sharing of knowledge
SAfMA	science local	legitimized at the national, regional scales often most important for local scale but little "power" at any scale; social networks and rituals at local level maintain its use	little interaction of science with local knowledge, though assessment tried to facilitate this; science still the basis for decisions at national level; local knowledge used for "survival"; local knowledge threatened by historical weakening and economic trends in Richtersveld National Park, local people important to conservation efforts and their participation is institutionalized
Northern Range	science	national, in the form of research organizations, public agencies, individuals	science has multiple cross-scale interactions: global, regional, and sub-national
San Pedro de Atacama	science traditional	national and local—for mining, tourism patchy local (elders hold it; only used for pastoral, agricultural activities); other local users try to protect local and traditional knowledge from further weakening national: law encourages participation in development and resource management	science still dominates ecosystem management at all scales "national" institutions assisted local social institutions trying to revive traditional knowledge for social identity purposes
India Local	combined and collaborative local and traditional ecological knowledge	People's Biodiversity Register (PBR) used at both local and national scales	PBR enabled science and local knowledge interactions and use for both local and national decisions
Eastern Himalayas	science local	dominates at local and higher levels via importance to economic activities survives at local level if artisan families still transmit; only use of knowledge can preserve local and traditional knowledge, which is threatened by disuse and decline in economic importance; no local control over resources	interaction between science and local people constrained by differences in logic and worldviews
Bajo Chirripó	indigenous local	local, via internal mechanisms; indigenous spiritual beliefs being lost, so social processes such as education being used to support its continued use	assessment a process for cultural validation, and recovery of knowledge allowed local people to interact with higher scales
Vilcanota	indigenous science	at the local scale, customs maintained; many involve rituals functions at national and higher scale	assessment aimed to achieve interaction of local and indigenous people with science and government (at higher levels) by empowering local people with the assistance of scientists and international donors science chose to defer to local knowledge for the assessment

Tropical Forest Margins	international research science	important at global level; expected to transfer to national institutions; increasingly learning from national and local	interaction at global and national scales enabled because the Tropical Forest Margins assessment was a boundary organization; coordination office provided institutional memory for interdisciplinary learning
	national research science	national and local research institutions important for training and learning	
	local	local; migrants bring outside knowledge from different locations	process-based knowledge worked better than location-specific knowledge for migrants, as well as for integration with science
Sinai	science	national and higher	science does not consult with Bedouins, although in the area of medicinal plants, interest is growing
	local, indigenous	special protection for knowledge on ecosystems and human well-being as they rely on it in crisis; local traditions, community regulation, and legal norms protect it; intergenerational transmission via stories and tribal meetings	

- the predisposition of the sub-global assessment team toward including local/traditional, practitioner, and multidisciplinary knowledge;
- the amount of time and funds devoted to the process of using multiple knowledge systems in the sub-global assessments; and
- the level of expertise and/or training available to guide the investigation and use of multiple knowledge systems in the sub-global assessments.

The first four factors, though distinct from an assessment process, can be specifically built into the process, or influenced during the initial stages of attracting interest in an assessment. The latter three can be designed and modified at the beginning of or during an assessment process. Future assessments would be wise to carefully consider how best to allocate time, resources, and expertise according to the availability and importance of different types of information and knowledge sources.

The impact of using local and traditional ecological knowledge was generally limited by the overall weakness of understanding how to best utilize multiple knowledge systems within the MA, as reflected in the conceptual framework, MA policy and methods, the type of scientists writing the assessments, and the composition of the assessment teams themselves. This problem is best illustrated by the absence of a chapter in the MA conceptual framework report (MA 2003) that discusses theoretical and practical issues around using multiple knowledge systems. This contrasts with separate chapters devoted to each of the other components of the MA framework: ecosystem goods and services, drivers, multiscale assessments, and responses.

The contributions of practitioner knowledge were largely limited by the MA assessment processes, which consulted with government officials, development agencies, local authorities, and NGOs to find out what their information needs were, rather than to investigate the type of knowledge these practitioners have about the management of social-ecological systems. Fuller engagement of assessment users and other practitioners as knowledge holders would require more attention to how NGOs and ministries use and acquire knowledge in policy- and decision-making. This is, as already noted, a fairly new field of inquiry mostly conducted by political scientists, institutional theorists, and some researchers attempting to better influence policy processes. Only the Tropical Forest Margins assessment seriously analyzed its own policy–research interactions.

Numerous scholarly and practical analyses exist on the issues of multidisciplinary research, participatory research and assessments, and the policy relevance of research. However, considerable transaction costs are involved in multidisciplinary and multistakeholder research. Working with local and traditional knowledge holders also requires time to build trust. The sub-global assessments had to weigh the trade-offs involved in achieving results versus working through the transaction costs of building a broad coalition. Recent work has shown that as social learning occurs, and firm working relationships are established, these costs are likely to decrease. In both Sweden KW and Tropical Forest Margins, networks had been functioning for at least ten years, and relationships were well established before the assessments began. In Sweden KW, the existing institution, the EKV, which has been in place since 1989, has the sole purpose of coordinating among knowledge systems and facilitating social networks that arise to resolve particular problems. The assessment was able to take advantage of this to avoid the transaction costs that other assessments had to face. The Tropical Forest Margins assessment team had also been working together for ten years; team members consciously reflected on the efforts required in the first few years to learn how to work together and appreciate all points of view. As a result, communication across disciplines and interests improved considerably.

Key issues that have been problematic for the sub-global assessments—knowledge documentation, validation, and use—can be addressed in two ways. First, local and traditional ecological knowledge documentation usually either requires leadership by the local people/communities involved or else an assessment team well trained in cross-cultural and participatory techniques. The validation process at the local level should not require the verification of local and traditional ecological knowledge against the standards of science. Instead, local methods of validation should

be upheld. Second, the assumption in the MA conceptual framework was that successful assessments share three basic features: they are scientifically credible, politically legitimate, and salient (that is, responsive to decision-makers' needs). It is questionable whether a small farmer, for example, who has expert knowledge, is a decision-maker at higher levels, beyond his or her day-to-day livelihood decisions. It is therefore necessary to understand the cross-scale institutional structure in which knowledge is used and decisions are made in the current location of an assessment. Future sub-global assessments, especially at the local level, could benefit from an analytical framework that more closely links institutions and knowledge. The scholarly literature on this is not as accessible to a wide range of readers as would be desirable, but an assessment process that truly bridges different knowledge systems should strive to overcome this problem.

The MA conceptual framework regarded elements of ecosystems as services and presented nature as ''other,'' something that people might act on or exploit but from which their lives are ontologically distinct. Yet, as this chapter illustrates, perceptions of ecosystem services vary across cultures. Thus the MA worldview may exclude key alternative local framings, such as a dynamic landscape perspective that views biological patterns throughout the region as being shaped through the interaction of social and ecological processes over time (Fairhead and Leach 2003; Batterbury and Bebbington 1999). The conceptual framework did, however, provide opportunities for modification and expansion, and some sub-global assessments incorporated other frameworks that challenged normal science and drew upon complexity science. There is much to learn from these adaptations of the MA conceptual framework as they challenge conventional scientific perspectives of ecosystems and human impacts within them.

In terms of methods, although each assessment reports using a range of participatory tools, it is far more difficult to tell what level of participation local users achieved (consultative or collaborative), and how much space the assessment created for mutual reflection and consideration of the offerings of multiple knowledge systems to the assessment goals and objectives. The task of an integrated assessment is particularly difficult, and demands extensive resources, since it needs to recognize the multidimensional nature of impacts, but also requires methods that are sensitive to a plurality of perspectives from diverse intellectual disciplines (MA *Policy Responses,* Chapter 3).

In terms of empowerment of local and indigenous resource users, there are only two clear examples of where the local populations were engaged to the extent that they took the lead in assessment design and implementation (Vilcanota, Bajo Chirripó). This could potentially happen in more local assessments if some of the previously identified conditions are met, such as the existence or establishment of local institutions that provide the catalyst for local knowledge to take the lead and engage science instead of the other way around. Another important condition that would help promote local leadership and empowerment is the involvement of expertise (whether local or from outside the communities) to facilitate mutual understanding so that one knowledge system is not dominated by another. Empowerment involves more than using local knowledge at a higher scale—it also means recognizing the intrinsic value and complexity of local knowledge as well as the existence of local institutions, and their ability to take the lead in the assessments and in the control over resource allocation and results of the assessments.

Each assessment was additionally confronted with practical implementation constraints. Common constraints included: limited funding, lack of data and information, and time constraints (due to the voluntary nature of the expert contributions and to the tight MA timeframe). Particularly important were the lack of local and technical expertise to conduct the assessment and to deal with conflicting knowledge, and lack of familiarity with appropriate tools and methods with which to study local knowledge systems. For example, SAfMA found that time constraints allowed for communities to respond to the scenarios that were presented to them, but not to evaluate these responses and apply critical thought (Cundill et al. 2004).

Thus the assessments' efforts to include local/traditional ecological knowledge varied in ability to cover all of the issues pertinent to the MA, for example envisioning plausible futures and suggesting policy responses. Local and traditional ecological knowledge contributes to policy recommendations and management practices if a strong and external institutional structure is in place, as in India Local, and Sweden KW. It is quite possible, in the two cases that took a more collaborative approach to working with local knowledge (Vilcanota, Bajo Chirripó), that with more time, a process for articulating local knowledge and linking it to decision-making processes may evolve. However, in the short term, the sub-global assessments have largely limited the role of local and traditional knowledge to a consultative one, helping to describe the state of ecosystems and human well-being within an established framework, but not taking full advantage of this knowledge system.

Using practitioner knowledge was also constrained by the MA framework and protocol, in that practitioners were limited by their role as assessment users. While they may also have been knowledge holders and indeed a number of the sub-global assessments reported that they contributed information, their major role was to express information needs, and hence guide the priority questions for the assessment. Knowledge becomes a slippery and value-laden issue when political and power interests are at stake, as they inevitably are in resource management. Future endeavors to assess the links between human well-being and ecosystem condition may well learn from the lessons provided by the MA sub-global assessments. These assessments, several of which are ongoing and will be a continuing source of information, provide a range of community-based case studies by which to examine how local and traditional ecological knowledge, practitioner knowledge, scientific knowledge, and the multiple disciplines therein, may work together for a common goal of sustainable ecosystem management and human well-being.

Appendix 5.1. Policies of the Sub-global Working Group Related to Local Knowledge and Community Assessments

These policies were developed by the Sub-global Working Group in 2002 to help guide their assessments in handling issues related to the use of different forms of knowledge.

Review Procedures

Sub-global assessments may develop review processes tailored to the circumstances of the assessment and the scale at which it is undertaken. Each sub-global assessment must provide a description of its review process to the MA Panel and Board at the time of its approval. Sub-global assessment review processes must meet the following criteria:

- the review process must be independent. An independent party not involved in the governance or operations of the sub-global assessment must have the authority to determine whether reviewer inputs have been sufficient, and whether the comments have been adequately handled;
- relevant governments (for the scale at which the assessment is conducted), NGOs, regional institutions and other organizations as appropriate must be contacted in advance to identify appropriate reviewers, and reviews should be requested from all these sectors;
- reviews should be requested with the aim of obtaining a balanced representation of views within the region involved, and among scientific, technical and socioeconomic perspectives;
- reviewers should include experts involved in the larger and smaller scale assessments within which the assessment is nested, or that are nested within the assessment;
- all written review comments, and the responses to those comments, should be provided in their original language to the MA Secretariat, where they will be kept on file.

Community-based Assessments

Community-based assessments generally will include significant amounts of information gathered from individuals, and based on local, traditional, and/or indigenous knowledge. These assessments should meet the review process criteria described above. In addition, they should also establish a process for ''validating'' information obtained through interviews, or based on such knowledge, as part of the application by the assessment to become a component of the MA. Typically, the validation process should include many, if not all, of the following features:

- self-critical review notes or reflective diaries: the researcher should record information on his or her own perceptions of where information being recorded may be incomplete, biased or in error;
- triangulation: multiple sources of information should be obtained, particularly for critical pieces of information;
- review by communities: members of the community should be given an opportunity to review the findings prior to finalization of the assessment;
- review by stakeholders at higher and lower scales: individuals who may not have detailed local knowledge of the area being assessed, but with knowledge of the region in which the assessment is located, should be given an opportunity to review the findings prior to finalization of the assessment.

For the MA working group assessment reports (including the synthesis report of the Sub-global Working Group), additional requirements exist for the use of information based on personal communication from individuals with local/traditional/indigenous knowledge, or direct input from working group members with such knowledge.

- Metadata concerning the personal communication (e.g. names of people interviewed, dates and types of notes recorded, presence or absence of self-critical review notes by the researcher, sources of triangulation, etc.) should be made available to the Co-Chairs of the working group.
- Where a working group member provides direct input of local/traditional/indigenous knowledge, the working group Co-Chairs should be given the following information:
  - basis for knowledge of the particular issues (e.g., length of time living in the area, individuals from whom historical information was obtained, etc.);
  - names and contact information for 1–2 persons who can be contacted for more information about the source.

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Chapter 6

Assessment Process

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Main Messages ***121***

6.1 Introduction **121**

6.2 Overview of Assessments that Aim to Inform Decision-making **122**

6.3 Adaptation of the Generic Assessment Process **123**

6.4 Exploratory Stages **124**
6.4.1 Exploring Potential Need, Scope, and Users
6.4.2 Boundary Conditions and Limitations
6.4.3 Funding Sources

6.5 Initiation and Design Stages **127**
6.5.1 Establishing the Demand for an Assessment
6.5.2 Assembling a Formal User Group
6.5.3 Establishing a Formal Governance Structure

6.6 Implementing the Workplan **135**
6.6.1 Assessing Ecosystem Services, Human Well-Being, and their Condition and Trends
6.6.2 Determining Drivers of Change
6.6.3 Developing Responses to Address the Drivers of Change
6.6.4 Developing Scenarios
6.6.5 Peer Review of Assessment Findings

6.7 Communication Strategy, User Engagement, and Capacity-building . . **136**
6.7.1 On-going User Engagement
6.7.2 Capacity-building
6.7.3 Developing Outputs and Communicating Findings

6.8 Reflections on the Assessment Process **139**

REFERENCES **140**

BOXES

6.1 Initiating an Assessment with Multiple Users: PNG

6.2 Engaging Users at Different Scales: SAfMA

6.3 The SAfMA Governance Structure

6.4 Interaction between the Advisory Committee and the Technical Team: San Pedro de Atacama

6.5 Capacity-building for Conducting the Technical Work: Vilcanota

6.6 Scenario Development: A Challenge for Many Sub-global Assessments

6.7 Sub-global Partnerships and Exchanges Program

FIGURES

6.1 Overview of Assessment Process*

TABLES

6.1 Sub-global Assessment Budgets and MA Funding Contributions

6.2 Users Involved in the Sub-global Assessments

6.3 Institutions Involved in the Technical Work of the Sub-global Assessments

*This appears in Appendix A at the end of this volume.

Main Messages

The sub-global assessment process was dynamic and iterative. Assessments such as the MA that link science with policy aim to meet user needs and support decision-making on complex issues by providing a critical, objective evaluation and analysis of information, including indigenous and local knowledge. The three main stages of the assessment process, with some overlap between stages, were: an exploration stage, a design stage, and the implementation of the resulting workplan, which included review, validation, and communication of the findings. Throughout these stages, on-going communication, user engagement, and capacity building were flexible and iterative components.

Each sub-global assessment process was bounded by political, socio-economic, and environmental circumstances. The heterogeneity of these circumstances, as well as constraints such as the availability of information or particular expertise, necessitated a variety of approaches to using the MA conceptual framework. An exploration of the boundary conditions of each sub-global assessment, including institutions that could potentially implement assessment outcomes, should have been, but was not always, included in the exploratory stages of the assessment work.

The sub-global assessments had to overcome multiple constraints to make progress. Constraints included lack of data and limited financial support. Further challenges included meeting the fixed MA timeframe, gaining the trust of various users, establishing and maintaining user engagement, securing technical leadership, and building the capacity to conduct multiscale, integrated assessments. These constraints limited the scope of each sub-global assessment, in terms of the number of ecosystem services and aspects of human well-being that were included, the temporal and spatial scales considered, and the knowledge systems incorporated. However, constraints sometimes led to innovative approaches to overcome them—for example, the development of a novel index for assessing biodiversity intactness (Southern Africa) and a consensus-based approach to the assessment of soil quality by multiple Quechua communities in Peru. Sub-global assessments that incorporated different knowledge systems required more time and resources.

Working with assessment users was an important part of establishing the demand for an assessment and identifying the processes that could use the assessment findings. Engagement with users at the beginning of the assessment process helped to shape the assessment around the questions that were most important and useful to users. The sub-global assessments showed three broad categories of need for an assessment: (1) to summarize and synthesize information on complex issues to support decision-making; (2) to strengthen the capacity of users to assess and manage their resources, or to participate in resource management; and (3) to address gaps in knowledge for resource management. For the first two categories especially, the assessments involved strong user engagement throughout the process.

A governance structure that provided a forum for discussion was necessary in assessments that involved a *wide range of users.* Many sub-global assessments considered diverse user needs and needed to manage the tensions among users which often centered on the allocation of resources for competing needs. In meeting user needs, sub-global assessments often prioritized the components of the MA conceptual framework to be addressed.

Strong user engagement can result in the assessment process itself being as important as the assessment findings. On-going communication with diverse sets of users in the sub-global assessments led to a greater appreciation and understanding of the links between ecosystem services and human well-being. Local capacity was built to undertake assessments. In some cases, such as in San Pedro de Atacama in Chile, assessments catalyzed groundbreaking discussions on ecosystem management among different sectors of the local population.

Applying the MA conceptual framework to on-the-ground activities proved to be a challenge. The MA conceptual framework, along with the procedural guidelines set out by the MA, guided the work of the 34 sub-global assessments. Some sub-global assessments incorporated multiple temporal and spatial scales and different knowledge systems in their assessments. Incorporating multiple scales necessitated meeting the challenge of developing common variables and measures—a challenge not attempted by most of the sub-global assessments. Most assessments were also not able to fully address the linkages between ecosystem services, human well-being, and drivers of change. The reasons for this were varied and included lack of data, capacity, and/or resources, including expertise in social sciences. During the exploration and design stages, the teams underestimated the effort that would be needed to cover the scope of the work being developed, the number and diversity of the disciplines that needed to be involved, and the challenges of obtaining the wide range of data needed.

Capacity-building activities need to be an integral component of any assessment, but especially a complex one such as the MA. The sub-global assessments demonstrated the need to strengthen capacity for conducting integrated assessments. Many sub-global assessments did not have all of the required expertise to assess the various components of the MA conceptual framework, and thus capacity-building activities were initiated within individual sub-global assessments. In addition, the number and diversity of the sub-global assessments participating in the MA provided an ideal opportunity for capacity-building across the sub-global network through the exchange of experiences and lessons learned. Future attempts at incorporating sub-global components into global assessment processes will have to invest considerable funds and time in developing the capacity to use common tools or standards across different locations, in order to add insight to the global assessment and increase both capacity and knowledge at sub-global scales.

Assessments need champions. In many cases, specific individuals played key roles during different stages of an assessment, for example as external facilitators in determining and establishing the demand for the assessment and in providing leadership and sustaining the assessment process. In some cases, small dedicated teams of people championed the assessment together.

6.1 Introduction

The MA conceptual framework (see Chapter 1), which explicitly links ecosystem services with human well-being, served as a common starting point for all of the sub-global assessments. Use of the conceptual framework helped the teams conducting the sub-global assessments to focus on selecting specific ecosystem services (such as food, water, fiber, etc.) and aspects of human well-being considered to be important. Using this as a start, the teams then assessed the conditions and trends of ecosystem services and human well-being, and the drivers of change. The conceptual framework also guided the analysis of interactions and trade-offs among services, and the incorporation of possible responses and plausible future scenarios to further inform this analysis. Thus the sub-global assessments became an experiment in the application of the MA conceptual framework.

The MA design meetings developed a set of working guidelines on the selection process for the sub-global assess-

ments, which was approved by the MA Board. The Sub-global Working Group refined and agreed to a set of policies that were first developed at the design meetings. The selection process and policy documents offered guidance on the technical aspects of the assessment work, including issues of working at multiple scales, intellectual property rights, transparency, data management, peer review, the use and validation of traditional or local knowledge, and user engagement (relevant excerpts from these documents are provided in later sections of this chapter). Many of these aspects were also considered to be important components of the process developed at the global level. Assessments that applied to become part of the MA were required to follow MA policies on these issues, and to agree to use the MA conceptual framework. (See Chapter 2.) Subsequently, meetings of the Sub-global Working Group provided a forum for exchanging ideas on approaches to the assessment work, and the broad range of expertise, experience, and disciplines within the group influenced the development of many of the individual sub-global assessments. The working group itself thus formed an important part of the assessment process.

The global MA assessment largely followed a process built on the experiences and lessons learned from other global assessments conducted by groups of international experts, such as the Intergovernmental Panel on Climate Change. Given their widely varying political, environmental, and socioeconomic circumstances, the 34 MA sub-global assessments had to adapt their particular processes to accommodate these varying circumstances and needs. In particular, the sub-global assessments had to meet the needs of diverse sets of users, including communities and their knowledge in a respectful and effective manner.

This chapter first provides an overview of assessment processes based on international assessments such as the IPCC and UNEP's *Global Environment Outlook*. From this overview, it is apparent that the three main stages of the assessment process are:

- an exploratory stage,
- designing the assessment, and
- implementing the workplan. Sub-components include: assessment of chosen variables, and review and validation of the findings. In many cases, it is expected that some of the assessment parameters will be adjusted as the workplan is implemented, including through the review and validation process.

A fourth component of the assessment process that spans all the stages is on-going engagement and communication with users. This includes capacity-building, iteration on the assessment focus and process with users, and the final communication of assessment findings.

The whole assessment process is bounded by the location-specific context of the assessment, including the political, socioeconomic, and environmental parameters. Outside of this, but crucial to the saliency of the assessment, are the discussion of plans for use of the assessment findings and for future work, as well as reflections on the assessment process and outcomes. (See Figure 6.1 in Appendix A.)

This chapter analyzes the different approaches taken by the sub-global assessments for each of the main assessment stages, the limitations and strengths of these different approaches, the constraints and challenges faced by the assessment teams, and concludes with lessons learned that may benefit future assessments of this type. This is not an assessment of the ''success'' of each sub-global assessment (as many have not even been completed) or of the findings across assessments; the latter is dealt with in other chapters of this volume. Additional reflection on the assessment process at the community level can be found in Chapter 11.

This chapter draws on various sources of material, including:

- reports produced by the sub-global assessments for the use of the MA or for publication; many are available on the MA website (www.maweb.org);
- responses from sub-global assessments to a set of questions developed by the chapter author team at the working group meeting in June 2003 in Stockholm;
- material from interviews conducted by the chapter author team during working group meetings (October 2003 in Prague and February 2004 in Alexandria); and
- direct experience and/or observations of the authors who are team members of various sub-global assessments, or of others during field visits.

6.2 Overview of Assessments that Aim to Inform Decision-making

There are many forms of assessment, which differ in both their aims and approaches. Common examples include environmental impact assessments and strategic environmental assessments. As an example, EIAs are used for assessing the impacts that activities associated with a particular project may have on the environment and society. SEAs have been used at a more strategic level, for developing policies, plans and programs for natural resource management at national and sometimes regional levels, and often incorporate sustainable development goals (Watson et al. 2003).

The last twenty years have seen the emergence of international assessments that provide objective scientific information of relevance to policy-making, particularly for the environmental conventions such as the United Nations Framework Convention on Climate Change and the Montreal Protocol on Substances that Deplete the Ozone Layer. These assessments are context-dependent, relating to a particular issue at a particular time and in a given geographical domain. They are often referred to as assessments that form an ''interface between science and policy''; examples include the IPCC and the Ozone Assessment. The MA is the most recent example of such an assessment, aiming to provide assessment information to multiple conventions and the private sector, among others.

In the case of assessments that link science and policy, ''assessment'' is defined as a process through which scientists, decision-makers, and advocates interact to define relevant questions or issues, mobilize experts and expertise (Clark and Dickson 1999), and provide options for decision-

makers to consider. The MA conceptual framework defines an assessment as ''a social process to bring the findings of science to bear on the needs of decision-makers'' (MA 2003). The process is thus as important as the quality of the end product in determining the effectiveness of an assessment (Cash and Clark 2001). An important feature of this type of assessment is to reduce complexity and add value by summarization, synthesis, and sorting what is known and widely accepted from what is not known or not agreed upon (see also Fabricius et al. 2004). Levels of certainty on the findings are often expressed, either qualitatively or quantitatively, based upon the collective judgment of the authors.

Recent experiences from assessments attempting to link science and policy (including the IPCC, UNEP's GEO, and the Global Biodiversity Assessment), as well as academic studies on assessments (including the body of work on assessment processes produced by the Global Environmental Assessment project based at Harvard), have found that certain attributes of the assessment process are crucial for building an effective link between science and policy. These include transparency, legitimacy, saliency (or usability), and credibility. To achieve attributes in the eyes of multiple users generally requires that assessment outputs (such as reports) be policy-relevant, but not policy-prescriptive.

Experiences from assessments such as IPCC, the global MA working groups, and the various MA sub-global assessments, have shown that the exploratory stage of an assessment is important, but challenging and time-consuming. During this exploratory stage, the different and sometimes conflicting interests of potential users, as well as the socio-economic, environmental, and political contexts in the areas to be assessed, have to be explored. The initial stages of exploratory work also involve an extensive search for a diverse set of users, whose subsequent involvement helps in elaborating the need for, and scope of, the assessment. During this stage, a formal governance structure for the assessment is discussed, and then established when the assessment work is initiated. Right from the initial stages of the assessment, engagement and sustained communication with targeted users is emphasized.

Once the exploratory stage has been completed, an assessment team with the appropriate expertise and geographical coverage conducts the technical work of the assessment. This includes a peer review process, which is a means for ensuring the quality and relevance of the technical work. The review process also provides feedback on interim findings to users, and thus forms part of the on-going strategy of engagement and communication with users.

A strategy for communicating the assessment findings is essential to ensure that these findings reach the intended audiences. In many assessments, this communication strategy consists of meetings where the findings are discussed with users (an example is the IPCC plenary), press releases, and publication of the reports. Engagement with the media is an important component, as this ensures broader dissemination of the findings. While the communication of findings occurs at the end of the process, on-going engagement and communication with users lays the groundwork for the final communication of assessment findings, ensuring that these findings address the information needs of users.

6.3 Adaptation of the Generic Assessment Process

The sub-global assessment teams and users had nuanced interpretations of what an assessment is, and often varying priorities for their assessment work. The design of each of the sub-global assessments was thus adapted to the needs and priorities of the user groups involved, and resulted in flexibility in the use of the MA conceptual framework and in the design of workplans for the sub-global assessments. The MA Sub-global Working Group accommodated these variations, and did not insist on sub-global assessments following all of the MA guidelines strictly, recognizing that a significant number of assessments would have found it difficult to adhere to all of the guidelines.

The three main variations in emphasis among the sub-global assessments were:

- summarization and synthesis of relevant information for the benefit of specific decision-makers. Examples include SAfMA Regional, SAfMA Gariep, Laguna Lake Basin, Downstream Mekong, Western China, Norway, Argentine Pampas, Caribbean Sea, Portugal, Coastal BC;
- focus on the process of strengthening the capacity of the users to assess and manage their resources. Examples include Sinai, Vilcanota, Bajo Chirripó, India Local; PNG, India Urban; and
- strong emphasis on research. Examples include Tropical Forest Margins, Sweden SU, Wisconsin.

These categories were not mutually exclusive, and many sub-global assessments included all three elements in their work. However, the emphasis (in terms of the effort allocated to activities associated with each element) varied among assessments. The relative emphasis depended on how each assessment process was developed and what types of users were involved. Other relevant determinants included the reasons for initiating the assessment, the scale of the assessment, the governance structure of the assessment, and the degree of user involvement in the process. The approaches that were taken by the sub-global assessments for each of these process components are analyzed in subsequent sections of this chapter.

A common feature of many of the community assessments was the inclusion of primary research and data collection as a part of the assessment process. (See Chapter 11.) Local assessments needed to have fine-grained data that were sometimes not available in the literature, and thus needed to be collected by the assessment teams (Fabricius et al. 2004). Examples include the two Southern Africa community assessments (SAfMA Livelihoods, SAfMA G-M), Portugal, the two Sweden assessments (Sweden KW, Sweden SU), Bajo Chirripó, Vilcanota, and PNG.

Intuitively, the sub-global technical teams and users found the MA conceptual framework easy to understand. However, the challenges of carrying out an assessment that

could populate all the boxes of the framework (direct and indirect drivers of change, ecosystem services, human well-being; see Box 1.2) were significant. Add to that the need to analyze scenarios, responses, and trade-offs, at multiple scales and involving different knowledge systems, and the resulting enterprise was overwhelming for many assessments. During the exploration and design stages, the teams underestimated the effort that would be needed to cover the scope of the work being developed, the number and diversity of the disciplines that needed to be involved, and the challenges of getting the information for the proposed assessments. However, in many cases, the challenges were overcome by developing innovative assessment approaches and/or by adjusting the assessment design to fit the context.

6.4 Exploratory Stages

Initial exploration of a range of issues was necessary to decide whether an assessment should be undertaken; these included potential users and their needs; the intended scope of the assessment; funding possibilities; and individual and institutional capacities in the assessment area. Institutions—defined as ''rules that guide how people within societies live, work, and interact with each other'' (see Glossary)—operate at various scales, such as global, national, and subnational, and on the basis of formal and informal rules (Chambers et al. 2005).

The focus of the sub-global assessments was often related to who was leading the exploratory stage, as well as to the social, political, and environmental characteristics of the potential assessment sites. The exploratory stages for MA sub-global assessments, beginning with the first contact between an assessment initiator and the MA Secretariat, and ending with the start of the assessment's design stage, ranged from four months to three years, and averaged about 12 months. In the cases of SAfMA, Portugal, and Western China, the exploratory stage was shorter, as these assessments were catalyzed by people who had a good knowledge of the MA conceptual framework coupled with the ability to engage quickly with users and attract institutional interest and funding. In some cases, a pilot assessment (for example, Norway and SAfMA) was conducted to explore the feasibility of conducting a full assessment and acquiring sufficient funds. The design of a sub-global assessment and subsequent development of the workplan were closely linked to outcomes of the exploratory stage (as discussed later in this chapter).

6.4.1 Exploring Potential Need, Scope, and Users

In many places, the lack of a consensus, or simply the lack of information, on the links between ecosystem services and human well-being was seen as sufficient justification for conducting a sub-global assessment. In many cases, the lack of organized information on ecosystem services, in conjunction with conflict over resource management, formed the basis of the need for an assessment. Researchers, in particular, were quick to grasp the potential of assessment work, and in most cases initiated the assessment process. For example, in the Salar de Atacama in Chile, a lack of access to information on water quality and quantity in one of the driest areas in the world made it difficult for the users of that resource to design an acceptable water management plan. Latent conflict existed among these resource users (including mining companies, tour operators, and the local communities), in part due to the lack of information. Because the MA was soliciting assessment projects and offering some funding, capacity-building, and a credible international network, researchers in Chile and in other places developed proposals for sub-global assessments where they recognized a potential need.

Once a potential site and focus had been identified, the person or group initiating the assessment contacted stakeholders in that region to further discuss the need and the focus for an assessment. Exploratory workshops preceded the majority of the sub-global assessments and strongly shaped the processes of these assessments. For example, in São Paulo, Brazil, the Forestry Institute, proposing a sub-global assessment of São Paulo city and the surrounding greenbelt, convened a large set of users in a workshop to explore environment-related uncertainties in their decision-making processes. The sub-global assessment in northern Wisconsin chose to explore potential user needs by developing an initial set of future scenarios. These were then discussed and refined with users in workshops, to help them understand what kinds of information they might need to manage their social-ecological systems in the face of uncertainties about the future. In general, governments, non-governmental organizations, research institutions, and the private sector were canvassed and those that showed interest were invited to become involved in the assessment, usually in an advisory capacity. National and regional scale assessments often did not include local users in this capacity, at least not at the early stages. Portugal, for example, conducted a broad assessment of national user needs, but only saw the need to include local users as advisors later in the process. In general, it was not difficult to generate interest in the assessments, since the benefits of information and international networking were apparent to most users, especially those who were technically knowledgeable, or informed. (See Box 6.1.)

It was often a challenge to convince resource users at the community level of the relevance or usefulness of conducting an MA assessment. This was especially the case where outside teams proposed to conduct an assessment at the local level—local users, interested in developing more direct strategies for improving their well-being, did not necessarily value the information benefits from an assessment. This was the case, for example, in the SAfMA local assessments and San Pedro de Atacama. In contrast, organizations and communities in Vilcanota, Bajo Chirripó, São Paulo, and Pune (India) that proposed local assessments themselves envisioned the MA as a tool for building capacity and supporting local management of resources. However, even in some of these cases, tangible rewards were proposed in parallel to assessment activities to respond to both material and information needs simultaneously. For example, in Vilcanota, greenhouses were built for community assessment teams. These complementary activities were often devel-

BOX 6.1

Initiating an Assessment with Multiple Users: PNG

In September 2000, the MA issued a call for proposals to undertake "sub-global" assessments at local, national, and regional scales. This document included a set of selection criteria that would be used to evaluate the proposals. The Call for Proposals was circulated among a group of social scientists that had previously had some connection to PNG's Biodiversity Conservation and Resource Management Program—an initiative that had been funded by the Global Environment Facility from 1993 to 1998. One of the key lessons of the program had been that local communities in these areas are far more interested in development than in conservation, because they have been conserving their ecosystems for thousands of years, but are now lagging in their access to modern health and education services because of their small and scattered populations.

In some coastal areas, high *marine* biodiversity values are associated with very high population densities, and local communities are keenly aware of the limited capacity of their *terrestrial* ecosystems to supply the services required in the face of continuing population growth. The MA Call for Proposals happened to coincide with a spate of letters and reports from a number of small island communities that indicated the extent of this awareness.

After some consultation among relevant stakeholders in the national capital, Port Moresby, an abstract of a pre-proposal was submitted to the MA in late October 2000.

In November 2000, a meeting of national stakeholders was convened to discuss further development of the proposal. This meeting was attended by representatives of:

- three national government agencies—the Department of National Planning and Monitoring, the Office of Environment and Conservation, and the National Fisheries Authority;
- three research institutions—the PNG National Research Institute, the University of Papua New Guinea, and the Australian National University;
- two international conservation organizations—Conservation International and The Nature Conservancy; and
- two donor agencies—UNDP and the Australian Centre for International Agricultural Research.

The meeting agreed that the University of Papua New Guinea and the Australian National University would enter into a partnership to develop a more detailed proposal.

Further work on the proposal came to a halt when the MA Board decided to cluster the sub-global assessments in four focal regions, none of which would include PNG. The work was revived in May 2001, when the two universities were asked to recast the proposal as a study of "small islands under pressure" in Milne Bay Province. This was now to be a component of the Milne Bay Community-Based Coastal and Marine Conservation Program, which had been conceived as a reincarnation of the earlier Biodiversity Conservation and Resource Management Program in a coastal and marine setting. The new program, like its predecessor, would be funded by the Global Environment Facility and implemented by UNDP, but would have a provincial rather than a national focus, and would be executed by Conservation International in association with the Milne Bay Provincial Government.

Since the conceptual framework and methodology of the Milne Bay Project were still aligned with those of the Millennium Assessment, the MA Board approved the "PNG Local" assessment as a sub-global assessment at the end of 2001. The Milne Bay project itself would have two scales of assessment—the provincial scale and the community scale—and this appeared to justify its designation as a "local" assessment. However, the proponents were still interested in the possibility of gaining financial and political support for a broader national or regional assessment of *coastal* ecosystems, for which the Milne Bay Project could be treated as a sort of pilot project.

In May 2002, a workshop was convened in Darwin (Australia) to explore this possibility. The cost of this meeting was borne jointly by the MA and the Australian National University. The regional focus of the workshop was defined as "Tropical Australasia"—a term that covered northern Australia, Melanesia, eastern Indonesia, and East Timor. Sixty individuals from different countries and organizations within the region attended this meeting, and identified a number of local sites where an ecosystem assessment would be warranted. Where a site met the group's criteria, it was assumed that local communities would also have an interest in the process of ecosystem assessment, although this was only established at a later date.

The delayed inception of the Milne Bay project caused it to be modified further to meet the needs of various users and donors. Given the financial and temporal constraints on the conduct of the assessment of coastal ecosystems, the process of user engagement at the local and community scales was designed around the interests of those organizations that were already working with local communities on issues related to the management of coastal ecosystems, or around the existence of separately funded initiatives to identify and respond to local community needs. At the national scale, the users of this assessment are still identified as the organizations that originally endorsed the idea of conducting an assessment of "small islands under pressure."

oped during exploratory discussions with users before the assessments were initiated.

6.4.2 Boundary Conditions and Limitations

The need for an assessment and its potential scope was dependent on political, socioeconomic, and environmental circumstances that formed what could be called "boundary conditions" for each sub-global assessment process. The presence of relevant decision-making bodies, including government agencies, private sector companies, community groups, etc., and their capacity to use different kinds of assessment findings, influenced the information generated by each assessment. The level of formal education, the social context, local knowledge, and the capacity of users were important factors in the design of the peer review process and the communication strategy. Both external boundary conditions (such as the relative powerlessness of Quechua people at the national level in Peru) and internal boundary conditions (such as having no economists on an assessment team) influenced the assessment process and the goals of each assessment.

The dynamics among different groups of users were part of the boundary conditions of the assessment process that had to be addressed early in the process to maintain credibility in the eyes of all users. Almost all assessments had multiple users, and many had to manage conflicts among users.

For example, in the Salar de Atacama in Chile, user groups included indigenous communities, mining companies, and tour operators, and managing their conflicting agendas was an important factor in the design of the assessment. Regular open meetings eventually led to a degree of collaboration that had not previously existed among these user groups. In the Caribbean Sea assessment, users included the governments of nine different countries (including the Netherlands and France) as well as intergovernmental organizations. The tensions among these users necessitated careful planning of the assessment process; for example, too much iteration as part of the process would have aroused suspicion on the part some users. In the assessment in Coastal British Columbia, Canada, politics was seen by some to be damaging to the assessment process, and politically contentious issues sometimes fractured the advisory board that was set up for that particular assessment.

A number of the sub-global assessments reported a distinct degree of user fatigue over the course of the assessment work. At all scales, the long process of an assessment can cause fatigue even within the groups directing or advising the assessment process. The Southern Africa assessment's regular advisory committee meetings drew fewer attendees as the years went by. At the local level, fatigue was not solely due to the MA assessment activities but to the compounded effect of yet another study on the livelihoods and circumstances of local people (suggesting, perhaps, that past research has not been as rewarding for the communities as it has been for the researchers). In particular, the San Pedro de Atacama and Southern Africa local assessments encountered such user fatigue, due to numerous previous research studies in their assessment areas. To help overcome user fatigue or avoid it completely, many sub-global assessments continuously tried to demonstrate the benefits of the assessment to local communities. User fatigue is a serious concern and one that the science community will have to manage in order to continue to engage with local communities in future assessments.

Boundary conditions also included constraints faced by the assessment technical teams, including limitations in finances, data, the methods available for undertaking certain analyses, and the technical or experiential expertise needed in specific fields or locations. For example, little verifiable information was available for the Vilcanota region of Peru, where few biophysical and social studies had been conducted, and what information was available was sometimes withheld from the assessment team due to the ''ownership'' of such information. In many assessments, early exploration of how these constraints could be overcome was not undertaken, leading to subsequent iterations of the assessment design throughout the process and slow progress.

It appears that the leadership (either by an individual or an advisory body) was an important aspect in ensuring that constraints did not impede the progress of an assessment (see discussion of governance structures below). Key actors or leaders prevented many emerging constraints from becoming permanent barriers by anticipating these constraints and addressing them promptly, including by helping to secure funds (from private and public sources, at national and international levels) or setting up the right technical teams. Furthermore, overcoming constraints was often very context-specific. In assessments involving indigenous and local communities, incorporating local and indigenous knowledge into assessments was a challenge. In the Bajo Chirripó, India Local, and Vilcanota assessments, key individuals led the challenging process of developing new methodologies to link science and traditional knowledge.

6.4.3 Funding Sources

The sub-global assessments had access to a certain amount of funding originating from the MA itself, which was an important factor in the initiation of the assessments. The MA originally planned to fund nested multiscale assessments in three regions: Southern Africa, Southeast Asia, and Central America. Only the Southern Africa cluster of assessments was fully funded by the MA; the other clusters never got off the ground for various reasons including lack of strong interest, capacity, and funding. Full funding enabled SAfMA to proceed rapidly to implement its workplan within the MA timeframe, designing an assessment based on the MA conceptual framework, with a formal governance structure in which the technical team and advisory committee met and interacted frequently.

With no other regional nested assessments, the Sub-global Working Group and the MA Board decided to distribute a large part of remaining funds as ''seed funding.'' The MA distributed thirteen seed funding grants ranging between $5,000 and $15,000 to enable ''candidate'' sub-global assessments to develop strong proposals and secure further funding for their assessment activities. (See Chapter 2.) Additional core funding was provided to ten assessments, but in almost every case the amount was less than $100,000. (See Table 6.1.) Other funding sources for the sub-global assessments included national governments, the Global Environment Facility, bilateral and multilateral donors, national and international NGOs including charitable foundations, and research institutions.

The funding necessary to conduct an assessment depended on the scale of the assessment and the size and nature of the technical team. For example, some had to pay technical experts to conduct the assessment; while in other assessments the work was conducted on a voluntary basis. Research institutions involved students in the technical work, and in some cases assessments contributed funding to graduate students to participate in the assessment work (for example, SAfMA). All assessments made use of in-kind funding to a large extent, often underestimating the amount of time needed to complete a full assessment and thus overburdening the assessment teams. Estimated budgets for the assessments ranged from $5,000 to $10 million, but in some instances only a small portion of the funding was secured. For instance, the Tropical Forest Margins assessment obtained less than 10% of its original budget, which limited the assessment activities and led to some redesigning and rethinking of the assessment midway through the process.

Funding was probably the single biggest constraint faced by the sub-global assessments. Many found it more difficult

to raise funding than they had anticipated. As a result, many assessment teams were unable to fully implement their workplan; lack of funding was a key factor in how far individual assessments eventually diverged from the original conceptual design for the MA sub-global assessments. The fundraising difficulties included the lack of donors for assessment work at the sub-global scale, and the lack of multilateral and bilateral donors with funding categories suitable for MA-type assessments; assessments were seen to have a strong scientific research emphasis that did not deliver immediate outcomes to the communities involved. In recent years, bilateral and multilateral donors, and international NGOs, have tended to focus on poverty reduction, and assessment teams found it a challenge to demonstrate how their assessments would ''directly'' reduce poverty (even if they could produce evidence that it would contribute strongly in many indirect ways).

Potential users such as governments and the private sector, while showing interest in the sub-global assessments, were not usually forthcoming with funding. This suggests that many potential users of the assessment results were not convinced enough of their usefulness to be willing to channel scarce resources toward assessments, and that sufficient demand for the assessment outcomes was not established. An example is the Colombian coffee-growing region, which—despite a proposal very much following the MA conceptual framework and an impressive technical team with local expertise—was unable to attract a major donor two years after the initial proposal. Although the government of Norway provided a significant part of the funding for the Southern Africa assessments, after a pilot assessment in Norway itself, the branch of government responsible for national environment policies decided not to fund a full national assessment of Norway. Even where sufficient user demand was established, assessments aimed at local decision-makers, especially in developing countries, were often unable to secure funding from cash-strapped local users and had to rely on donors who were not the immediate users of assessment findings.

Delays in access to already secured funds also caused many assessments to lag within the MA timeframe. In Papua New Guinea, the release of secured UNDP/GEF funding was delayed for two years, and the assessment team had to rework their plans in order to move forward with small components of their full work program in the interim. In Bajo Chirripó, the assessment costs for the local level work were low, and yet interruptions in funding caused the assessment work to stop and start several times. This also caused frequent redesigning of the process. Most assessments tried to make do with the amount of funding they were able to raise and fit their process to the available budget, which caused components of the process to be removed from the original assessment design.

6.5 Initiation and Design Stages

Following the exploratory stage which identified users and their needs, the formal initiation of a sub-global assessment saw the establishment of an advisory committee and a technical team for the assessment. The design stage then built on the MA conceptual framework, where the design of the assessment was fine-tuned to the needs of users and the realities on the ground in different locations. This involved selecting which ecosystem services and other aspects of the MA conceptual framework to include in the workplan, and deciding how to allocate resources to each component of the assessment process. At this stage, assessment teams also needed to determine whether it was appropriate and/or desirable to conduct their assessment at multiple scales, according to MA guidelines. In many cases, the design stage also included an exploration of whether traditional and/or practitioner knowledge could, or should, be included in the assessment. Discussion of these topics can be found in Chapters 4 and 5, respectively.

The design stage did not actually end with the start of the core assessment work, as the process was iterative and continued to evolve as the workplan was implemented and as constraints and realities were faced. This section explores the process that was needed to design each assessment; further analysis of how the assessment teams assessed the condition and trends of particular ecosystem services and aspects of human well-being, response options and scenarios, is presented in those respective chapters in this volume.

6.5.1 Establishing the Demand for an Assessment

General interest and support from assessment users was enough to launch the sub-global assessments, but in some cases the engagement of decision-makers was superficial. Sustained user engagement is important for many reasons, especially for providing guidance on the direction of the assessment work, raising funds, and acting on the findings. (The importance of sustaining user engagement and developing an effective communications strategy is discussed later in this chapter.)

Some sub-global assessments were designed to respond to a specific demand for information from a particular set of users. For example, the government of China, after some initial discussion with UNEP and the MA Secretariat, contributed funding to develop the Western China assessment, in order to inform their 50-year development plan for that region. Similarly, the Caribbean Sea assessment was developed to provide information to support the proposal by the region's heads of state and government to have the United Nations designate the Caribbean Sea as a ''special area in the context of sustainable development'' (Caribbean Sea). Because these assessments were responding to information needs for specific purposes, the value of the work was immediately clear to the users and gained widespread support.

In some cases, assessments were initiated to provide general information bases, without a clear mechanism for using the information in decision-making. The information bases were seen to potentially help improve decision-making at various levels and by different types of decision-makers (at least 10 assessments fit into this category, including SAfMA, San Pedro de Atacama, Laguna Lake Basin, Downstream Mekong, and Portugal). For example, while it was clear that baseline information on water quantity and quality in the

Table 6.1. Sub-global Assessment Budgets and MA Funding Contributions. Funding sources for each assessment can be found at **www.millenniumassessment.org/en/subglobal.** * = an assessment scaled back its activities (for example from a national to a local assessment) and readjusted the budget accordingly.

Sub-global Assessment	Budget ($)	MA Seed Funding ($)	MA Core Funding ($)	Funding Acquired by December 2004 (% secured of total budget)
Altai-Sayan	750,000	15,000		2%
Tropical Forest Margins	3,000,000	6,780	80,000	7.50%
Coastal BC	3,200,000			100%
San Pedro de Atacama	100,000 (originally 200,000)	15,000	70,000	100% (of readjusted budget*)
Caribbean Sea	118,000		70,000	100% (of readjusted budget*)
Downstream Mekong	55,000 (originally 130,000)	5,000	55,000	100% (of readjusted budget*)
India Local	110,000	10,000		100%
Sweden KW		*on-going university-funded research*		
Laguna Lake Basin	90,000	10,218	74,000	100% (for stage 1)
Northern Range	48,000		41,000	100%
Norway	70,000			100% (for pilot stage)
PNG	500,000		44,000	100%
Portugal	135,000		32,500	100%
SAfMA	900,000		846,250	100%
Sweden SU		*on-going university-funded research*		
Western China	4,000,000		127,780	50%
Argentine Pampas		*on-going funded research*		
Bajo Chirripó	155,000	15,000		50%
Colombia	TBD			0%
Eastern Himalayas	25,000	50,000		50%
São Paulo	1,546,000			2%
Sinai	230,000	13,350		100%
Indonesia	95,000	29,854		75%
Central Asia Mountains	515,000	10,850		N/A
Arafura and Timor Seas		24,370		N/A
India Urban	5,000			100%
Wisconsin		*on-going university-funded research*		
Vilcanota	127,000	21,000	45,650	50%

Salar de Atacama desert in Chile was necessary in order to develop effective policy on water access in the area, it was unclear when, how, and by whom this information was to be used. The San Pedro de Atacama assessment team found it necessary to continuously justify the need for an assessment at each advisory committee meeting because some users were not convinced that the findings would be used by key decision-makers. On the other hand, some users saw the benefit in obtaining access to assessment findings, which could then be used to lobby decision-makers.

In places where formal decision-makers generally do not make environmental issues a priority, it was still found to be useful to undertake an assessment of ecosystem services and human well-being, as long as a receptive set of potential users of the findings or process was identified. For example, civil society groups were the primary identified users in the San Pedro de Atacama, Sweden KW, Vilcanota, Bajo Chirripó, Wisconsin, Sinai, and India Urban assessments.

Assessments that were initiated because of a pre-determined use for the outputs had some success in raising funds,

developing the process rapidly and keeping on track to deliver the outputs (examples include Coastal BC, Western China, and India Local). One caveat is that even when the use for the assessment outputs was clear to the technical team, the ability of local or national institutions to implement the assessment findings was often a limiting factor in the usefulness of the work. For example, in Bajo Chirripó, a local NGO attempted to develop resource management plans with local communities based on assessment findings; however, the communities did not have established institutions to implement the management plans effectively. This was also the case for regional assessments where effective cross-border resource management requires close cooperation between neighboring nations. For example, responses for rebuilding fish stocks in the Caribbean Sea, developed as a result of assessment findings, can only be effective if all nations in the region cooperate to fund conservation programs or implement new policies. The secretariats of regional intergovernmental bodies such as the Association of Caribbean States and the Caribbean Community will be the main agents for obtaining support from the various national governments in such endeavors.

6.5.2 Assembling a Formal User Group

The size and composition of the user groups in the sub-global assessments reflected the scope of each assessment. At early stages of the assessments, the technical teams were encouraged to include a wide range of users. The selection process document outlining the criteria for becoming an MA sub-global assessment included the following statement:

> *The assessment must centrally involve the intended users as stakeholders and partners throughout the process, from methodological design through the review process. Based on the experience with the initial abstracts submitted for sub-global assessments in October 2000, this criterion may be one of the most challenging for sub-global assessments to meet. One purpose of the multiple step selection process outlined in this document is to provide candidate sub-global assessments with the time (and in some cases financial support) necessary to establish a significant level of user involvement. (MA 2002)*

The paragraph refers to a ''multiple step selection process,'' which led most of the sub-global assessments to pass through a candidate stage. The rationale for this was to allow assessment teams time to develop diverse user groups that could contribute to the design of the assessments:

> *An important feature of an integrated assessment is the examination of the interlinkages among traditional ''sectors'' of development such as agriculture, water, energy, transportation, and ''environment.'' Another important feature is the integration of both natural and social sciences in the assessment process. All of the MA sub-global assessments must reflect these two core features of integrated assessment in the composition of the teams undertaking the assessment. (MA 2002)*

Almost all sub-global assessments involved national, regional, or local government agencies as users. (See Table 6.2.) A large number of the sub-global assessments identified local communities, NGOs, universities, and research institutes as important users in addition to the government agencies. The private sector (for example, the tourism industry, mining companies, logging companies) was involved in only five assessments, despite the MA goal to support a greater role for the private sector in environmental decisions (MA 2003). Indigenous communities were involved in six assessments. A useful exercise conducted by some sub-global assessments was to start their work by analyzing what user information needs the assessment could address, initially including as broad a set of users as possible (examples include Portugal, Norway, San Pedro de Atacama, Northern Range).

The choice of the user groups depended on the scale and focus of the assessment. In assessments that incorporated multiple scales, different users were identified at different scales, as would be expected. (See Box 6.2.) The initial choice of users was very much in the control of the people proposing the assessment, although most assessments remained open to interested parties. Because the involvement of key decision-makers is an important factor in the uptake of assessment findings, networking skills are particularly useful in an assessment hoping to link science with policy in order to capture the interest of high-ranking individuals in key institutions.

6.5.3 Establishing a Formal Governance Structure

The governance structure of an assessment is crucial to provide legitimacy and credibility to such an endeavor (Eckley 2001). Governance structures that encourage continuing and effective communication among scientific experts, decision-makers, and other user groups are likely to increase saliency for all groups. However, it is the tensions and divergent interests of these various groups that the governance structure also has to manage. The assessment process needs to respond to the changing and varied needs of its users, but also remain credible and focused.

Each sub-global assessment was influenced by governance at at-least two levels—the level of the MA Sub-global Working Group and the level of its own governing body. Given that the policies of the Sub-global Working Group were agreed on before many sub-global assessments joined the process, it was not surprising that the user groups of several individual assessments did not understand, value, or simply could not comply with all of the MA guidelines. Additionally, the global MA process and the governing bodies of individual sub-global assessments were focused on different priorities and outcomes for the assessment work. The global MA process wanted the sub-global assessments to contribute new knowledge and insights to a global understanding of the links between ecosystem services and human well-being while maintaining local relevance. The sub-global assessments themselves were not averse to these goals, but their primary motivation was to meet the needs of their own users at sub-global scales, with priorities ranging from developing local capacity to manage ecosystems to compiling baseline data on ecosystem services in previously

Table 6.2. Users Involved in the Sub-global Assessments

Sub-global Assessment	National, Regional, or Local Governments	Indigenous People	NGOs	Private Sector	Local Community Organizations	International, National, or Local Research Institutions	Multilateral Agency	Distributed Policy-makers
Altai-Sayan	X				X			
Tropical Forest Margins	X		X			X		X
Coastal BC	X	X		X				
San Pedro de Atacama	X	X		X	X	X		
Caribbean Sea	X		X			X		X
Downstream Mekong	X				X			
India Local	X		X		X	X		
Sweden KW	X				X	X		
Laguna Lake Basin	X		X			X		
Northern Range	X		X	X	X	X		
Norway	X			X				
PNG	X	X	X		X	X	X	
Portugal	X		X	X	X	X		
SAfMA	X		X		X	X		
Sweden SU	X				X	X		
Western China	X					X		
Argentine Pampas					X	X		
Bajo Chirripó		X			X			
Colombia	X					X		
Eastern Himalayas	X		X		X			
São Paulo	X							
Sinai		X				X		
Indonesia	X							
Central Asian Mountains	X		X			X		
Arafura and Timor Seas			X					
Indian Urban			X					
Northern Wisconsin						X		
Vilcanota		X	X		X			

unstudied areas. Ultimately, governance at the level of each assessment was responsible for the evolution of each sub-global assessment process.

6.5.3.1 Advisory Committees

The typical governance structure in many assessments included an advisory committee and a technical committee, which in some cases had overlapping roles (for example, SAfMA, Portugal, Western China, Laguna Lake Basin). The role of the advisory committee varied across assessments but included providing guidance to the technical team on what needs the assessment should meet (for example, Northern Range, SAfMA, and San Pedro de Atacama), ensuring progress, reconciling the needs of different users, distributing funds in an objective and transparent manner, and providing a platform for outreach. (See Box 6.3.) The presence of an advisory committee in some cases produced greater capacity for structuring the work and keeping the assessment process on track, especially where the advisory committee was given a formal role (for example, in SAfMA, Western China, and Coastal BC). In some assessments run by very small teams or by scientists focused on on-going research, advisory committees were either nonexistent or less involved in the assessment work (for example, in the Swedish assessments, Bajo Chirripó, and India Local). In most cases, this did not damage the credibility of the assessments to the local users, but engagement with a broader range of users was not achieved. In the cases of assessments that were continuations of on-going research, the lack of an advisory committee was made up for by governance structures unrelated to the MA, resulting in processes that diverged the most from the MA conceptual framework.

Ideally, the advisory committee manages the balance of power between the assessment users and within the technical team. A valuable part of the assessment process proved to be the dialogue and debate both between the advisory group and the technical team and among technical experts with different analytical models and expertise looking at the same problem (Fabricius et al. 2004). SAfMA, for example, was characterized by a high level of dialectical debate and

BOX 6.2

Engaging Users at Different Scales: SAfMA

The Southern Africa sub-global assessment was conducted at three scales in a fully nested design. The SAfMA component assessments were a regional scale assessment, two basin scale assessments, and several community assessments. The regional assessment covered 19 countries in mainland Africa that lie south of the equator. Nested within the regional assessment were the basin scale assessments covering two major drainage basins: the Zambezi and Gariep. Within SAfMA Zambezi and SAfMA Gariep, several "community-based" assessments were conducted at varying scales, from village to city to one that was a broader sub-region.

SAfMA Regional users included the Southern African Development Community environment, water resources, agriculture/food security, and development portfolios; national governments; the private sector; the media; and the public. SAfMA Gariep and SAfMA Zambezi contributed to the needs of governments, conservation, and agricultural agencies as well as catchment management authorities, respectively in South Africa/ Lesotho and Zambia/ Malawi/ Mozambique/Angola/Tanzania/Zimbabwe. For local assessments, the users were local communities, municipalities, common property associations, as well as local teachers and scholars.

Individuals representing user groups were invited to contribute to SAfMA as members of User Advisory Groups, one each for each of the various component assessments. Some were invited to be part of the SAfMA Advisory Committee that provided oversight and guidance. The different categories of SAfMA users were engaged in a variety of ways, ranging from their appointment on review panels to involvement in intensive workshops at regional, basin, and local scales.

SAfMA also engaged users through the "SAfMA Fellowship Program." Individuals from stakeholder organizations were invited to apply for SAfMA Fellowships, which entailed participation in SAfMA activities, reviewing SAfMA documents, and assisting with the outreach and dissemination of SAfMA materials. SAfMA fellows also acted as bridges between SAfMA and other programs in the region, and also took SAfMA messages to their organizations and countries.

Motivation and interest were secured by ensuring that users interacted and maintained dialogue with the technical experts, receiving regular feedback on how the assessment was progressing and in turn keeping the technical team informed of their expectations.

BOX 6.3

The SAfMA Governance Structure

SAfMA had a hierarchical governance structure consisting of the Advisory Committee (AC) and the Technical Committee (TC). The ten members of the advisory committee were representatives of the users at the regional scale and were responsible for representing the interests of the different stakeholders, balancing the various interests within the region, creating a receptive policy environment for the work and output of SAfMA, endorsing the SAfMA outputs, and directing the work of the technical teams. The technical committee consisted of the principal investigators of the various SAfMA component technical teams and were responsible for designing the assessment, harmonizing the methods, communicating among component assessments, monitoring progress, and producing a multiscale synthesis report. The SAfMA coordinator, appointed by the advisory committee and based at one of the stakeholder institutions in the region, had the role of linking the various SAfMA components and assisting the technical committee in the completion of its duties. The coordinator also acted on behalf of the advisory committee to oversee the implementation of approved plans. The advisory committee interacted with and maintained dialogue with the technical committee, received regular updates on how the assessment was progressing and in turn kept the technical committee informed of stakeholder expectations and perceptions.

emerged with novel assessment methods and tools that could be tested and compared across scales. Effective governance ensured that most debates were constructive and that the technical team remained productive. (See Box 6.4.)

6.5.3.2 Technical Teams

The technical work in the sub-global assessments was carried out by teams that typically included people of different backgrounds (associated with disciplines and/or cultures, thus ensuring that different views and knowledge were incorporated from the inception), gender, and age. The composition of the technical team varied depending on the scope, scale, and audience of the assessment. Team sizes in the sub-global assessments varied from four to more than a hundred people (larger teams included Western China, Tropical Forest Margins, and Coastal BC). Most teams involved about 30–40 people, although the bulk of the work was often done by a few people (often the youngest members of the assessment teams, with guidance from the more experienced/senior members). Teams that were based at research institutions engaged younger researchers in the technical work, thus building capacity for future assessment work; for example, in the Wisconsin assessment, graduate students were responsible for carrying out different components of the sub-global assessment over a number of years.

In some assessments where there was a high degree of local technical expertise (for example, São Paulo, Laguna Lake Basin, the Argentine Pampas), the technical teams carrying out the assessment were composed of mostly local researchers; within the local context, this increased the legitimacy and credibility of the results. In some cases, local experts or people who had previously established working relationships with user communities conducted the technical work, which automatically increased the level of trust between users and the technical team (examples include Northern Range, Caribbean Sea, SAfMA Livelihoods, Vilcanota, Bajo Chirripó, India Local, Sweden KW). This had the additional benefit of facilitating the incorporation of the assessment findings into decision-making processes. The decision to have outside researchers assessing local ecosystem goods and services can be tricky, as local users may see the outsiders as either credible experts or intruders. This perception can change as the assessment progresses; for ex-

BOX 6.4

Interaction between the Advisory Committee and the Technical Team: San Pedro de Atacama

Three months after the San Pedro de Atacama assessment started, an advisory committee was established consisting of 16 representatives from the diverse user groups in the project area: a local irrigation association, mining companies (4 environmental and sustainable development managers or general managers), the forestry and protected areas agency, the regional environmental agency, the regional indigenous peoples agency, a governmental program for indigenous people development (ORIGENES), the mayor of San Pedro de Atacama, the Indigenous Development Area (a governmental initiative for indigenous people development), a regional university, the Indigenous Peoples Council (*Consejo de Pueblos Atacameños*), and three tourism operators.

A trust-building process was necessary in order to have the various members of the advisory committee effectively working together. The issue of water scarcity provided an opportunity for members to sit down together to address a common issue. A number of conflicts over water scarcity had occurred previously between indigenous people and miners, and the opposed groups had never sat down formally to discuss the issue until brought together by the assessment. The discussions enabled the advisory committee members to:

- share information, knowledge, and experiences;
- attempt to integrate diverse perspectives;
- participate in a new forum for communication; and
- ultimately go beyond the initial agenda to discuss a broader range of topics in an unconstrained manner.

It was decided, however, that the advisory committee would not take final decisions on technical and budget issues for the assessment; it took on a consultative role in the governance of the assessment. RIDES, the institution conducting the technical work, retained the right to veto any suggestions from the advisory committee. In this assessment, the advisory committee did not play a technical advisory role, and therefore was not involved in checking the quality and robustness of assessment findings. Nonetheless, informal reviews of interim findings by the advisory committee likely contributed to more robust findings in several sections of their report. After five advisory committee meetings, this approach was evaluated as successful and appropriate to the objectives defined at the outset.

ample, in the San Pedro de Atacama assessment, outside researchers overcame initial distrust among some stakeholders.

6.5.3.3 Involvement of Institutions in Technical Work

Different types of institutions were involved in the technical work of the assessments. In most cases, these were research institutions, but in some cases this role was assumed by governmental and/or nongovernmental organizations. (See Table 6.3.) Although it is too early to come to conclusions about the impact of institutional involvement on assessment outcomes, in terms of the process, the assessments associated with research institutions—especially universities (for example, in the SAfMA, Sweden KW, Sweden SU, and Northern Range assessments) and larger research institutions (for example, the CGIAR centers in the Tropical Forest Margins assessment)—benefited from the high capacity to undertake assessments, in terms of both expertise and the availability of students and collaborators.

Table 6.3. Institutions Involved in the Technical Work of the Sub-global Assessments

Type of Institution	Examples of Sub-global Assessments
Research Institutes (often have high diversity of technical expertise)	Colombia, India Local, Laguna Lake Basin, PNG, Portugal, SAfMA, Sweden KW, Sweden SU, Tropical Forest Margins, Downstream Mekong, Argentine Pampas, San Pedro de Atacama, Caribbean Sea, Northern Range
Government	Coastal BC, Caribbean Sea, Norway, São Paulo, Western China, Colombia
Nongovernmental Organizations (can be small research institution)	Altai-Sayan, San Pedro de Atacama, Northern Range, India Urban, Caribbean Sea
Community-based Organizations (can be an NGO)	Bajo Chirripó, San Pedro de Atacama, India Local

The institutions involved in the sub-global assessments have in general been dedicated to environmental and sustainable development issues. Some assessments tried to extend the ownership of their work to other sectors (such as the private sector and non-environment government ministries). In the Argentine Pampas, on-going agricultural assessment work that had traditionally involved only research institutions from the agriculture sector expanded to include an assessment of human well-being in the region. This required new partnerships with researchers from other disciplines and organizations, a process that could lead to the development of more integrated responses to ecosystem change.

6.5.3.4 Governance-related Challenges

The sub-global assessments demonstrated a serious trade-off between an exhaustive consideration of user needs, meeting the timeline and design requirements of the MA, and their own assessment workplans. This trade-off meant that not all the ecosystem services or user needs identified were considered in some assessments (for example, SAfMA, Northern Range, Caribbean Sea).

The various advisory committees and technical teams had to decide how much effort to expend on building capacity among users so that they could become fully involved in the process, as well as how many different user groups to include in the process. In Bajo Chirripó, the process was temporarily stalled at the stage of coming to a consensus on user needs and their relationship with the MA conceptual framework. Before moving on with the assess-

ment work, it was important to this assessment for local indigenous communities to understand the MA conceptual framework and ecosystem concepts and to link these concepts to their own worldview. Due to technical, communication, and epistemological hurdles, this was a slow process. (See Chapter 5.) The Tropical Forest Margins assessment conducted a study on the challenges of conducting integrated assessments and found through an online survey of their technical team that there was an institutional contradiction on this issue. The majority of those polled agreed that the project,

> *. . . should reach out to a wider representation of groups within current countries (where the Alternatives to Slash-and-Burn consortium is active), including more and different types of local community associations and conservation groups, local government and civic organizations, local and national NGOs, policymakers and other officials at various levels (Tomich et al. 2004).*

However, the majority of those polled also agreed that since the collaborators of Tropical Forest Margins assessment,

> *. . . are overloaded with work, (the assessment) should focus on delivering results for farmers and national policymakers, who are core stakeholders (Tomich et al. 2004).*

This contradiction between idealism and realism reflects the trade-offs between advancing the assessment process and increasing the legitimacy and saliency of the assessment. This trade-off is exacerbated by the ''relatively little understanding of the tradeoffs involved in participation decisions; for example, how increasing public participation might increase political legitimacy, but might decrease the scientific credibility of the research designed to support the decision making'' (Clark et al. 2002). A way of overcoming this conflict and addressing the trade-offs was to establish a governance structure in the early stages of the assessment.

6.6 Implementing the Workplan

Having designed the assessment and developed the workplan to meet the goals of the assessment, the next step was to conduct the technical work. These stages were not completely sequential and compartmentalized, but rather iterative and closely interactive. In this section, the emphasis is on the process—examining the constraints and challenges faced by the technical teams during the assessment process and extracting the lessons learned.

As part of the implementation of the workplan, the technical teams assessed the various components of the MA conceptual framework according to their assessment design, modifying the process when confronted by constraints or evolving user needs. An analysis of the findings across the sub-global assessments can be found in Chapters 3, 7, 8, 9, and 10.

One of the lessons learned from the early stages of the technical work of the sub-global assessments was that many teams did not have the capacity to be able to effectively analyze the links between the drivers of ecosystem change, ecosystem services, and human well-being. In some cases, this changed as the assessments progressed and the technical teams instituted different ways of building capacity. (See Box 6.5.)

A crucial aspect of the MA, at both the global and sub-global scales, was the integration and synthesis of findings across the components of the conceptual framework and across scales. This integration and synthesis was often attempted toward the end of the process. The experience of the sub-global assessments suggests that planning for this latter stage at the beginning of the process greatly facilitated it, and that sufficient time should be designated for group discussion and reflection on assessment findings in order to produce integrated output. (Further discussion on how this was achieved can be found in Chapter 4.)

To ensure that the outputs from these activities were both credible and salient, the MA developed guidelines for conducting a peer review process. In many cases, a mechanism for validating information from practitioner knowledge or informal sources had to be incorporated into the review process (discussed later in this chapter).

6.6.1 Assessing Ecosystem Services, Human Well-Being, and their Condition and Trends

Ecosystem services in the MA conceptual framework were categorized into provisioning, regulating, supporting, and cultural services; this categorization was followed by all sub-global assessments. Biodiversity was a special case: in some cases, it was considered to be an ecosystem service, as well as a condition underlying the services provided by ecosystems. Human well-being had multiple components, including many aspects not directly reliant on ecosystem services.

In each sub-global assessment, the services and the human well-being aspects considered to be most important by users and the technical teams at that scale were included. The determination of what to include was based on consultation between the users and the technical team and took resource constraints into consideration (including time, money, and expertise). Many assessments included provisioning services (such as food, fiber, and water) and cultural services (mostly focusing on tourism), but not many considered supporting and regulating services, often due to lack of data. A common constraint was the lack of baseline data against which to measure changes in the condition of ecosystem services. Components of biodiversity (for example, distribution of certain taxa) were relatively well-assessed by most sub-global assessments.

Most sub-global assessments did not look at the links between ecosystem services and human well-being. Trade-offs among ecosystem services were also not considered in many of the assessments. This may have been because links and trade-offs were only addressed toward the end of the assessment process, when there was less time and fewer resources to complete the complicated analysis.

Data, mostly qualitative, on both ecosystem services and human well-being were obtained from reports, books, publications, and interviews with users. In general, the sub-global

BOX 6.5

Capacity-building for Conducting the Technical Work: Vilcanota

In some assessments, the necessary technical expertise for undertaking the assessment work had to be developed. Even within assessments that had access to experts from a large number of disciplines, teams often chose to train students and young scientists to undertake much of the work.

In the Vilcanota assessment, the local Quechua indigenous people provided the focus for the assessment work. The assessment was led by a local NGO based in Cusco (Asociación ANDES), but several Quechua communities were directly involved in assessing the state of ecosystem services in their mountain ecosystem, their own well-being, and potential responses to the changing environment based on their own values and priorities. The assessment process focused on the development of tools that the local people could use to assess their ecosystems, thereby both contributing to the MA process and helping the Quechua to disseminate their knowledge to other local communities as well as to the wider scientific and policy arenas.

One aspect of this capacity-building was the training of a local women's video team. The medium of film is closer to the Quechua way of communicating knowledge through oral tradition. This training was seen as critical to effective local participation in the assessment. The video products were produced in the Quechua language and were used for capacity-building and disseminating findings widely within Quechua-speaking regions. Filming the assessment process met specific challenges of a local assessment undertaken by local people themselves, by increasing the opportunity for local people and local organizations to access, understand, and apply the information and knowledge generated (or simply recorded) during the assessment process. The first video that the local team produced followed a series of meetings held in local villages to understand and adapt the MA conceptual framework to the Quechua worldview. As part of dissemination of their knowledge to the wider scientific community and contribution to the MA, the video was presented at the MA Bridging Scales and Epistemologies Conference in Alexandria, Egypt, in March 2004.

Asociación ANDES trained *tecnicos,* or technicians, in all the Quechua communities involved in the assessment. The technicians learned the basic concepts of the MA conceptual framework and participated in discussions on how to integrate the MA ecosystem and human well-being concepts with the Quechua worldview. At a technical meeting in June 2004, involving about one hundred participants from three local communities, the technicians were able to lead the community members through exercises focused on the assessment of soil quality at different altitudes in the region. As all the community members farm intensively and possess intimate knowledge of their land, they were usually able to reach consensus in their assessments. Both men and women participated in equal numbers at this meeting, although only one 1 out of 14 technicians was female. The members of each community chose the technicians democratically and, during a feedback session on the assessment process at the end of the meeting, the participants demonstrated satisfaction with the technicians and the process as a whole. The only complaint from some of the men present was that they too wanted to learn video techniques.

assessments provided a descriptive rather than a quantitative measure of the condition of ecosystem services. Observations and lessons learned include:

- In most cases, it was difficult to consider the full range of ecosystem services that the users and technical team thought was important.
- The teams concentrated on the ecosystem services for which it was easy to obtain quantitative or qualitative data (usually provisioning services), rather than those crucial to the human well-being in that location.
- The links between ecosystem services and human well-being were not well-addressed, mostly due to lack of data and/or methods. Approaches for this analysis should be investigated at the beginning of the assessment process, and the inclusion of more economists and social scientists should be an important consideration in the assessment design.
- Many assessments initially constrained by lack of data have now assembled baseline data and built significant capacity that will benefit future assessment work in those areas.

6.6.2 Determining Drivers of Change

The technical teams and user groups determined the drivers of ecosystem change within the sub-global assessments through literature reviews and discussion. The assessments focused on the drivers considered most pertinent to the changes in ecosystem services and human well-being occurring at the scale of the assessment. In most cases, the degree of ''controllability'' over each driver at that scale was examined, and both the technical teams and the users found that the classification of drivers as endogenous or exogenous was more useful within their processes than the classification of direct or indirect. Local and traditional knowledge was used to identify and determine the effect of drivers in some assessments. (See Chapter 7.) The sub-global assessments also identified the speed at which the drivers act, a measure that is likely to tie into the responses that can be developed for these drivers of change.

As with the analyses of the current status and trends of ecosystem services, many sub-global assessments cited lack of information as a constraint to identifying and analyzing drivers of change. In some cases, the choice of the drivers to include in the analysis may have been data-driven.

Observations and lessons learned include:

- Decision-makers prefer the classification of drivers based on the degree of control they could potentially exert over each driver.
- In the early stages, many sub-global assessments had neither the data nor a general understanding of the links between drivers of change (direct or indirect), ecosystem services and human well-being in their area. This changed as the assessments progressed, probably through discussions within their user groups and with the sub-global working group.
- A deeper understanding of the links between drivers of ecosystem change, ecosystem services and human well-being is needed to develop and discuss policy options. Participatory scenario work could facilitate such discussion. (See Chapter 10.)

6.6.3 Developing Responses to Address the Drivers of Change

In the context of the MA, responses are a range of policies and actions that affect the state and functioning of ecosystems. (See Chapter 9.) Responses to changes in the supply or quality of ecosystem services or in measures of human well-being would usually be developed to intervene with the direct and indirect drivers of change.

The technical teams, in consultation with the users, developed potential responses to changes in ecosystem services and/or human well-being or assessed past responses already put in place by local decision-makers. The appropriateness of responses was assessed using both scientific information and local and traditional knowledge. Most sub-global assessments identified responses to only the direct drivers of change and did not on the whole address many responses to indirect and/or exogenous drivers. Some sub-global assessments developed response options as part of scenario-building, with close involvement of users who would then be in a position to implement them.

Observations and lessons learned include:

- When developing response options, there is a need for understanding the complex links between the drivers of change, ecosystem services and human well-being, as well as the associated trade-offs.
- A lack of clear mechanisms or institutions for implementing responses, especially at the national or regional scale, acts as a disincentive for developing responses and in fact for conducting an assessment. One such mechanism would be to ensure that the advisory group is in a position to act on or implement the responses. In many cases, this may not be possible, but it is still important to identify a group that can make use of assessment findings and influence decision-making processes.

6.6.4 Developing Scenarios

Scenarios, or storylines representing a set of plausible futures, have been used in the last few decades for making decisions in the face of uncertainty. (See Chapter 10.) Uncertainty can result from lack of information (or ignorance of what information is available) or disagreement over what is known or knowable about the dynamics of interactions between humans and ecosystems. In developing scenarios, a set of questions or issues is first developed in conjunction with users, often revolving around key uncertainties. Next, findings of the assessment on the current state and recent trends of a system are examined and alternative pathways the system might take in the future are identified. The next steps involve developing the storylines and quantifying them, which is often an iterative process. The sub-global assessments that developed scenarios utilized methods based on these steps, but ended up with very different kinds of scenarios. This was due to differences in local priorities, the composition of groups involved in scenario development, available funding for scenario activities, among other factors. Many assessments did not develop scenarios at all.

The approaches taken to developing scenarios included exploring existing scenarios produced for that area or similar areas; adapting elements of the scenarios developed by the MA Global Scenarios Working Group; and developing new sets of scenarios based on scenario literature with input from users and other experts. The best way to initiate scenario work was found to be trial and error, although access to experts helped. A few sub-global assessments developed a set of steps (for example, SAfMA Livelihoods) or a framework based on their understanding of what was needed to develop the storylines, often through repeated workshops attended by users and the technical team. Largely qualitative stories based on major drivers of change were developed, usually for a 15–25 year time horizon (although some extended to 50 years). Communication of the scenario outcomes and feedback (including validation) from users was found to be helpful in identifying response options; it also provided a means of interaction between the technical team and the advisory group (for example, in the Portugal assessment).

The constraints to developing scenarios included timing and funding. (See Box 6.6.) The lack of existing scenarios and/or models that incorporate ecosystem services and their links to human well-being was a major constraint to scenario development at the sub-global level. In addition to having to explore methods for linking ecosystem services

BOX 6.6

Scenario Development: A Challenge for Many Sub-global Assessments

Scenario development in almost all sub-global assessments was hampered by two main factors: timing and funding.

Timing issues were related to the completion of the global scenario storylines and the scenario development exercises in each sub-global assessment. When those sub-global assessments developing scenarios had reached a stage where they needed guidance on scenario development and how to establish a link between the global and sub-global scenarios, the global storylines were not yet available in their final form. This led several sub-global assessments to independently create scenarios, where they had the expertise to do so. Assessments that did not have the technical capacity to develop scenarios simply did not even attempt it. Another timing issue was related to the late stage at which scenario development was usually attempted in the assessment process of each sub-global assessment. The focus in most sub-global assessments was primarily on examining drivers of change and the conditions and trends of ecosystem services and human well-being, these priorities were usually completed before scenario development was initiated.

Funding issues were directly related to these timing issues. When components of the assessment needed to be omitted because of lack of funding, scenarios were often the primary target. In many sub-global assessments, scenario development was considered somewhat less important than other assessment aspects. Even within SAfMA, where a full set of scenarios was developed, it was noted by a member of the technical team that priority was given to what was considered to be the main task of assessing conditions and trends of ecosystem services and human well-being: "Although scenario development was elaborate compared to the other assessments, less emphasis was actually given to scenarios and more to condition and trends" (Reinette Biggs, personal communication).

and human well-being, the teams also had limited capacity to develop scenarios/models that integrate conditions and trends of ecosystem services with drivers of ecosystem change and possible policy responses. Scenario-building was the most unfamiliar component of the MA conceptual framework to most sub-global assessments and this often led to delays in initiating scenario activities. (See Chapter 10 for an explanation of what scenarios are and how they were developed by sub-global assessments and the global MA Scenarios Working Group.)

Observations and lessons learned from the process of building scenarios include:

- Even with a general lack of existing scenarios and models that encompass links and feedback loops between ecosystem services and human well-being, appropriate expertise within the sub-global assessments or the ability to link the global scenario-building activities to the sub-global assessments can be drawn upon to develop scenarios.
- Assessment teams without previous experience can learn to develop scenarios through an iterative process, in consultation with global scenarios experts, and through trial and error.
- Draft scenarios can be used during the early stages of a sub-global assessment to initiate discussions with decision-makers on the key uncertainties they face, and on what information the assessment could supply to improve decision-making in the face of these uncertainties (this approach was used in the Northern Highland Lake District, Wisconsin, for example.)

6.6.5 Peer Review of Assessment Findings

The review process, through which the assessment findings are validated, is an essential step in the assessment process. The involvement of users in the review process also forms part of the communication strategy and contributes to on-going user engagement in the assessment process (discussed in the next section). Each sub-global assessment was responsible for developing the specific process for validating its findings, drawing on the MA guidelines on an acceptable review process and in line with the general MA requirement to include a formal review process. The most common form of validation used was peer-review of assessment reports. With the exception of SAfMA, Portugal, Northern Range, Caribbean Sea, Coastal BC, Laguna Lake Basin, and Sweden, most sub-global assessments had not yet conducted a formal peer review of their findings when this volume was being written. The MA thus organized a formal review of interim reports from each assessment to facilitate the writing of this volume. Many assessments found this ''mid-term'' review useful to the development of their work; it led to major revisions in some reports.

Based on the experiences of those assessments that underwent a review separate from the MA-managed review process, it was common for the advisory committee and technical team to develop a list of potential reviewers. The people on the list of reviewers were selected on the basis of their technical expertise and/or decision-making capacity, and were representative of the users of the assessment information and beneficiaries of the ecosystem services assessed. The existence of an advisory committee often aided in the review process, as the advisory committee included representatives from many user groups that could participate as reviewers of the assessment (see earlier discussion). The reviewers often included a combination of local people (usually with some technical expertise) and international experts, including those involved in other MA working groups (this combination of local and international reviewers was observed in SAfMA, Coastal BC, Laguna Lake Basin, Western China, Tropical Forest Margins, Northern Range, and Caribbean Sea). In some sub-global assessments (for example, SAfMA, Tropical Forest Margins, Sweden KW), the review process included the publication of assessment findings in peer-reviewed journals, which aided in the communication of results to a wider audience. In all cases, peer-review was an onerous and time consuming process, but was considered to be important for strengthening and ensuring the credibility of the assessment findings, and for obtaining feedback from users. In many sub-global assessments, as with the IPCC and the MA working groups, publicly available responses to the review comments were important for adding to the findings' transparency and objectivity.

Though peer-review is the most accepted form of validation, it is also important to ensure that appropriate techniques are used for getting input from different users at various scales. For example, in SAfMA, as the scale of assessment moved from regional to local, so did the balance of information availability—from formal, documented data typically regarded as being in the ''scientific'' domain to informal, tacit information contained in the life experiences of local residents and in folklore transmitted by oral tradition, or perhaps documented but not according to scientific standards (Fabricius et al. 2004). The distinction between ''formal'' and ''informal'' knowledge is not as clear or strict as is often thought, and at the level of broad principles, similar rules of use and validation apply to different types of information, although the validation procedures may differ. (See Chapter 11 for a discussion on local approaches to data collection and validation.)

6.7 Communication Strategy, User Engagement, and Capacity-building

An important task for the assessment teams was to identify their target audiences. The audiences were often defined by the scale of the assessment, but were not limited by this factor, and therefore were sometimes broader than the user group. In some cases, an effort was made to communicate the process and findings to the wider decision-making community and the general public with the aim of influencing understanding of the links between ecosystem services and human well-being in a wider policy context.

6.7.1 On-going User Engagement

The sub-global assessment experiences highlight that on-going interactions between assessment users and the techni-

cal team are necessary to maintain interest in the process and results, as well as to keep the focus of the work aligned with the needs of the users. In the Northern Range assessment, for instance, advisory group meetings were often combined with meetings of the technical team so that advisory group members could provide input and feedback on the assessment findings and process. In the São Paulo assessment, government users at a workshop were encouraged to prepare a realistic flowchart of their decision-making processes; this allowed the technical team to refine the focus of their assessment work to supply specific information needed to improve decision-making.

Where user involvement was strong, the assessment *process* became as important as the assessment findings. In the Portugal assessment, for example, the advisory group and other users participated in all of the research team meetings, and were active in scenario-building and in the qualitative assessment of ecosystem services. Their involvement was a capacity-building exercise (for example, in the development and use of scenarios) but also prepared them for the uptake of the assessment findings.

Strategies for user engagement were often dependent on the scale of the assessment and the networking capacity of the technical team. Other factors included the capacity of various users to engage in the process and understand the results; language differences; and the overuse of scientific terminology or jargon. The sub-global assessments used a range of diverse methods and techniques for engaging users, including workshops (such as in the Caribbean Sea and the Northern Range), interviews, focus groups (Northern Range), open houses, and informal consultations. More innovative methods were explored as well, such as SAfMA's use of theater for presenting scenarios, the involvement of schoolchildren in assessments in San Pedro de Atacama and the Western Ghats in India, and the filming of meetings and discussions for local dissemination in Vilcanota. These methods were developed in order to incorporate local knowledge for sharing and validating information, communicating results, and designing and discussing scenarios.

6.7.2 Capacity-building

Capacity-building activities served to overcome a variety of constraints faced by many of the assessments; in many cases, the outcomes of these activities are as, or more important than, the assessment findings. Capacity-building occurred at several stages of the assessment process. In some sub-global assessments, capacity-building activities began with an explanation of the MA and its conceptual framework to the potential users. In other cases, capacity-building focused on developing methods or expertise for data gathering and analysis, scenario-building, and analysis of responses.

Sub-global assessment teams met at MA Sub-global Working Group meetings to share methodologies and lessons learned, which helped in the capacity-building process. In addition, the MA provided funding under a program for partnerships and exchanges among sub-global assessments. (See Box 6.7.) Experience sharing within the network of sub-global assessments was key in allowing assessments with fewer resources to overcome some constraints, including the challenges associated with aspects of the technical work.

6.7.3 Developing Outputs and Communicating Findings

The communication of findings from the sub-global assessments was principally aimed at influencing the way decisions are made at the scales relevant to the assessment. The MA subscribed to the notion that outputs developed for communication should be relevant to policy-makers, but should not tell them what to decide (that is, they should not be policy prescriptive).

At the MA working group level, most assessments agreed with MA policy that assessment findings and conclusions "should be policy-relevant, but not policy-prescriptive." At local levels, however, some assessments planned to produce recommendations and enter directly into the policy arena, which they considered to be appropriate because their advisory body also included decision-makers. At the international level, for a scientific or technical team to develop recommendations is potentially contentious because it calls into question the objectivity of the scientific findings. One option that has worked in international conventions is for an advisory committee to develop recommendations based on the findings of the technical reports. This strategy may be used by some sub-global assessments in the future.

At the Sub-global Working Group level, the main product is a technical volume summarizing the experience and lessons of the MA sub-global assessments (that is, this volume). The audience for this volume includes decision-makers at the local, national, and international levels, and in particular organizations or donors interested in undertaking or funding sub-global assessments. In addition, each sub-global assessment provided two peer-reviewed documents for dissemination by the MA:

- a summary or interim report (depending upon their stage at the time of writing in late 2003), which provided information on the main conclusions (or interim findings) of the assessment. In October 2004, the sub-global assessments updated these reports, and they were subjected to a process of peer-review coordinated by the MA Secretariat, after which they were revised one last time; and
- a two-page summary, included in Appendix B of this volume, highlighting the main findings and/or process aspects of each assessment.

The MA facilitated the inclusion of several sub-global assessments in a documentary on the MA, produced by Earth Report for the BBC Network (released in March 2005). Some of the major findings and experiences of the sub-global assessments were reflected in this production.

For each sub-global assessment, the development of outputs and the communication of findings were heavily dependent on the schedules of the individual sub-global assessments. At the time of writing this chapter, SAfMA, India Local, San Pedro de Atacama, Caribbean Sea, North-

BOX 6.7

Sub-global Partnerships and Exchanges Program

A the first meeting of the MA Sub-global Working Group, held in Panama in June 2002, participants discussed the need to establish and enhance linkages among the MA sub-global assessments. These linkages were conceived of as being vertical (across scales and with the global working groups) and horizontal (among sub-global components of the MA). The MA initiated the program on partnerships and exchanges as a mechanism to foster linkage opportunities, in order to realize the full potential of the MA process and of individual sub-global assessments. The sub-global assessment teams had widely varying strengths but many were dealing with similar issues—albeit in very different social-ecological contexts. Two of these exchanges are summarized here.

San Pedro de Atacama–Western China Exchange

The San Pedro de Atacama assessment team participated in an exchange with the Western China sub-global assessment. Both teams were assessing the state of their drylands and modeling the hydrological systems in their particular regions. When the Chilean technical team visited the Institute of Geographical Sciences and Natural Resources Research in Beijing, the discussions revolved around issues of desertification, desalination, hydrology, modeling, and information systems. Despite the differences between these two projects in terms of infrastructure, number of researchers involved, and scale of the assessment, the San Pedro de Atacama team identified several useful lessons from Western China that could be applied to their own assessment:

- *Data management.* This included information management, metadata management techniques, and spatial data management based on remote sensing datasets.
- *Technical capacities.* The Western China project shared experiences on the use of satellite imagery to study changes in land use patterns.
- *Water resources management in drylands.* This subject was common to both assessments, but the way it was approached was quite different. Western China focused on identifying the processes that affect the ecosystem (for example, desertification and salinization) and analyzed the implementation of large technical solutions. The Chilean approach was limited to a baseline analysis of the current situation and put emphasis on the interrelation between human and social aspects and the ecosystem.

The exchange activity was completed with the visit of a Chinese technical team to Chile. Among the aspects that were seen to be of particular relevance for the Chinese teams were: the peculiarities of the Chilean dryland ecosystem and the Chilean approach to linking human well-being with ecosystem services, including techniques for including local stakeholders in the assessment process.

The Chilean and Chinese teams continue to foster further collaborations, including comparative research on subjects such as watershed hydrological modeling and training on land use information management.

Bajo Chirripó–Vilcanota Exchange

Both the Vilcanota and the Bajo Chirripó sub-global assessments were conducted by local NGOs with the strong participation of indigenous communities. The Quechua communities in the Vilcanota sub-region of Peru live in deforested rural areas and practice subsistence farming. These Quechua communities still live according to their traditional value system and have safeguarded their customs and beliefs from rapidly encroaching "globalization" factors associated with tourism and national education policies. In contrast, the Cabecar communities of Bajo Chirripó in Costa Rica have managed to safeguard their tropical forests, but not their traditional practices or beliefs. Preliminary assessment work identified the need to reestablish traditional ecosystem management practices, and the belief system that underlies these practices, in order to improve the state of ecosystem services and human well-being in Cabecar communities. To initiate MA activities in both Peru and Costa Rica, the assessment technical teams recognized that the MA conceptual framework would have to be adapted to their local worldviews in order for the concepts to resonate with the communities involved in the work.

The technical teams and community leaders from both assessments met in June 2004 in Cusco to discuss the adaptation of the conceptual framework to indigenous worldviews. Both groups agreed that an explicit acknowledgement of the need for reciprocity between humans and their environment is lacking in the MA conceptual framework. The Cabecar participants were fascinated by the traditional lifestyles of the Quechua people and their knowledge of agriculture and astronomy, but expressed concern for the deforested state of the mountains, the low levels of biodiversity, and the poverty of the people. After observing a large meeting of several Quechua communities that were gathered to assess the state of their soil, the Cabecar team commented that they would like to involve larger groups of local people in their assessment, and specifically more women.

ern Range and Portugal, had started to disseminate their final findings, although some assessments had distributed interim findings to wide audiences.

The task of communicating findings was most often undertaken by the lead institution involved in each sub-global assessment. Generally, the sub-global assessments found it difficult to plan for this final stage, partly because technical teams were more focused on completing the core assessment work than on thinking ahead to outreach strategies, and partly because communication strategies are complex and they evolved as the assessment process matured. As such, many sub-global assessments did not include this aspect of the assessment in their overall budget. To offset some of these costs, the MA made some extra funds available to sub-global assessments for communications.

One of the most important aspects in defining the target audience for communication of findings was scale. Some assessments aimed their principal communication activities at intergovernmental processes and specific regional programs (Caribbean Sea), whereas others focused on national governance structures (Northern Range, Portugal), or on communities and local governing bodies (San Pedro de Atacama, India Local, Vilcanota). The MA encouraged assessment teams to develop materials that could be disseminated outside the assessment locations, to amplify both the reach and impact of the work.

Within each sub-global assessment, the outputs produced (or planned) were diverse and depended both on the needs of the users and on the financial resources available for product preparation and dissemination. The most com-

mon products included reports and summaries (SAfMA, Northern Range, Caribbean Sea, Portugal, Tropical Forest Margins), brochures and pamphlets (Chile, Northern Range, SAfMA, Portugal, India Urban), atlases (Colombia), and educational material such as posters (Northern Range, Caribbean Sea, SAfMA) and calendars (San Pedro de Atacama, Northern Range). Vilcanota produced a video for the dissemination of findings from the assessment process to local communities, but it also attracted attention at the international level when shown at meetings and conferences. As a means of communicating their outputs, the sub-global assessments planned various activities. These included mainly workshops or meetings with users and involvement in decision-making processes at different levels.

Where funding was available, communication partners (such as media or communication specialists) were employed to enhance the potential reach of the assessment findings. SAfMA engaged such a partner and benefited primarily from the media contacts and networking the partner provided. The assessment team learned, however, that more targeted efforts to reach specific decision-makers was not within the domain of communication specialists, and was more effectively accomplished by their own team members. The lead institution in both the Northern Range and Caribbean Sea assessments initiated a program on environment and resource education, based on the knowledge and experience they gained from the assessment work; these institutions will provide on-going forums for the dissemination and use of assessment findings. Some assessments (for example, Tropical Forest Margins, Sinai, São Paulo, and Sweden) took advantage of the well-developed communication process of the global MA, and participated in national user forums organized to disseminate global MA findings, press conferences, and other activities.

Observations and lessons learned include:

- Individual consultation with users followed by group discussion is useful in getting user input and establishing effective communication.
- Advisory group members are a powerful means for communicating the assessment findings, and members should be chosen with this role in mind.
- Establishing the expected outcomes and benefits of the assessment during initial interactions with users increases users' substantive engagement and on-going participation.
- Communicating the MA conceptual framework to the various users builds capacity to understand its main concepts.
- Including a diversity of users in the review process is an important aspect of validation and feedback and thus a part of the communication strategy.

A number of challenges to effective communication noted by the assessment teams include:

- language barriers;
- the difficulty of communicating technical and scientific findings to the general public;
- limited access to the target audience, due to lack of telecommunication facilities and other factors;
- distrust between assessment users as a result of past and current conflicts;
- poor motivation of assessment users; and
- lack of funding, expertise, and capacity.

6.8 Reflections on the Assessment Process

The full challenge for all the sub-global assessments was to conduct an integrated assessment with a focus on both ecosystems and human well-being, and communicating the results to a set of users prepared to use the findings that were relevant to them. This required a multidisciplinary team and a governance structure to integrate the findings from different fields. Energetic and committed team members, adequate data, and readily available assessment methods (or the ability to develop them) were major factors contributing to the completion of the planned work.

Completion of the work is not, however, a measure of an assessment's success, as the full impact of the process and resulting reports can only be seen a number of years after completion of the work, in many cases. When an assessment is completed, it still remains to be seen whether decision-makers at different levels will be convinced of the importance of recognizing the links between ecosystem services and human well-being. An assessment of the impact of the sub-global assessments should be conducted at some point in the future, which will also allow further insights to be developed on the effectiveness of the sub-global assessment process. One measure of success will be if assessment teams and users capitalize on the capacity that was built during these processes and establish on-going programs of assessment and engagement.

All assessment teams cited the MA conceptual framework as a useful tool for communicating the link between ecosystem services and human well-being to their assessment users, as well as for organizing their work. At the local level, some communities rejected the worldview presented in the MA; achieving local ownership of the assessment process necessitated the translation of components of the framework into local terms and concepts. The result was increased saliency at the local level (and increased probability of continuing on with the assessment work)—as well as increased difficulty interpreting and comparing results across the sub-global assessments and with the results of the global-level assessment. (See Chapter 11.)

Some issues remain unaddressed regarding the philosophy that was used to argue for the ''bottom-up'' approach to designing the assessment processes. Ideally, assessments would have met the needs of local users, while at the same time enabling the MA to analyze the interactions among components of the MA conceptual framework in various sociopolitical and environmental contexts. In order to do this, the procedural criteria of the Sub-global Working Group would have had to be more strictly followed, and the sub-global locations selected in a top-down manner to ensure a strict multiscale, nested assessment design and greater comparability among assessments. Assessments could

have also been chosen strategically to allow for the analysis of particular components of the conceptual framework. For example, areas that are strongly affected by specific ''indirect'' drivers (such as rapid demographic changes in Southeast Asia, sociopolitical changes in the former Soviet Union, or changes in cultural and religious values in Bhutan) could have been selected in order to link these indirect drivers to a set of direct drivers of change in ecosystem services. The original concept was to be more selective in this manner (see Chapter 2); however, assessment selection was ultimately driven by user demand and interest on the part of scientists and the user community.

An important question to ask is whether it would have been possible to achieve the goals of greater comparability across assessments and global relevance without sacrificing the numerous assessments that did not seem able to meet strict top-down criteria, or sacrificing the saliency of the assessments to their local users? It should be noted that the initial attempt to be more stringent with the MA criteria was derailed by funding and capacity constraints. Future attempts at incorporating sub-global components into global assessment processes will have to invest serious amounts of money and time into developing the capacity to use common tools or standards across different locations, if they seek to add insight to the global assessment and increase both capacity and knowledge that is useful at the sub-global level.

SAfMA has provided the MA with its desired archetype of a multi-scale, nested assessment, and the full collection of sub-global assessments represents a colorful network of assessments that are salient to their local users and are developing diverse processes for assessing ecosystem services and human well-being. It is not unreasonable to suggest that many assessments in the latter category will have just as lasting, or possibly more lasting, an impact in their local contexts. In addition, some of the slower and more creative processes developing in places like Vilcanota, Peru, or the Western Ghats in India will offer insights at the global level on how various forms of knowledge can be used to inform decision-making, and what processes can be used to gather and validate the necessary information in an assessment.

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Chapter 7

Drivers of Ecosystem Change

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Main Messages ***143***

7.1 Introduction **143**

7.2 Background: Major Global Trends **144**

7.3 Individual Drivers **145**
7.3.1 Drivers within the MA Conceptual Framework
7.3.2 Individual Drivers in the Sub-global Assessments
7.3.3 Driver Categories
7.3.4 Spatial Scales and Driver Classification
7.3.5 Driver Scale and Dynamics

7.4 Integrating Drivers **157**
7.4.1 Assessment Process
7.4.2 Cross-scale Impacts of Drivers
7.4.3 Interactions among Drivers and their Impacts
7.4.4 Patterns of Interaction

7.5 Drivers and Thresholds **164**

7.6 Implications for Interventions **166**
7.6.1 The Problem of Multiple Effects of Interventions
7.6.2 Intervening in Drivers: Multiscale Issues
7.6.3 Adaptive Co-management of Social-ecological Systems

7.7 Conclusion **169**

REFERENCES **169**

BOXES

7.1 Crises in Ecosystems

FIGURES

7.1 Indirect Drivers of Ecosystem Change at Regional and National Scales Identified by the Sub-global Assessments*

7.2 General Overview of Population Growth and Gross Domestic Product per Capita in Selected Countries with Sub-global Assessments

7.3 Direct and Indirect Drivers across Scales and Their Classifications as Exogenous or Endogenous

7.4 Relationship between Spatial and Temporal Scale of all Drivers Considered in the Sub-global Assessments

7.5 Three Modes by which Global and National Drivers "Trickle-down" to the Local Scale

7.6 Interactions among Drivers, and Their Impacts, in Smallholder Agriculture

7.7 Interactions among Drivers, and Their Impacts, in the Extraction of Natural Resources

7.8 Interactions among Drivers, and Their Impacts, Arising from Economic Development Strategies

7.9 Interactions among Drivers, and Their Impacts, from the Growth and Expansion of Urban Areas

7.10 Interactions among Drivers, and Their Impacts, Related to Tourism

7.11 Interactions among Drivers, and Their Impacts, Related to Extreme Events

TABLES

7.1 Changes in Global Population, Food and Energy Production, and Economic Output, 1950–93

7.2 Summary of Methods Used to Identify and Assess Drivers of Ecosystem Change in Sub-global Assessments

7.3 Emphasis of the Scientific Perspective on the Identification and Assessment of Drivers

7.4 Drivers of Ecosystem Change at the Local Scale

7.5 Drivers of Ecosystem Change at the Sub-national Scale

7.6 Drivers of Ecosystem Change at the National Scale

7.7 Drivers of Ecosystem Change at the Regional Scale

7.8 Drivers of Ecosystem Change at the Global Scale

7.9 Classification of Drivers by Temporal Scale

7.10 Relationship between Speed and Directness of Drivers

7.11 Major Processes of Driver Interaction across the Sub-global Assessments

7.12 Modes of Interaction among Processes

7.13 Interventions in Interacting Drivers: Examples from Selected Sub-global Assessments

*This appears in Appendix A at the end of this volume.

Main Messages

Drivers of ecosystem change act in distinct ways in different regions. Although similar drivers were present in different regions, the processes through which these interacting drivers cause ecosystem change differed among the sub-global assessments. For example, while the three regions of Latin America, Central Africa, and Southeast Asia in the Tropical Forest Margins assessment have the same set of drivers of land use change (deforestation, road construction, and pasture creation), the processes leading to change are different across these three regions. Deforestation driven by small-scale swidden agriculture is more widespread in upland and foothill zones of Southeast Asia than in the other regions of the tropics. In Latin America, state-sponsored road construction followed by colonizing migrant settlers, who in turn practice slash-and-burn agriculture, causes deforestation in lowland areas, especially in the Amazon Basin; large-scale pasture creation for cattle ranching causes deforestation almost exclusively in the humid lowland regions of mainland South America. The spontaneous expansion of smallholder agriculture and fuelwood extraction for domestic uses are important causes of deforestation in Africa.

The biophysical drivers of change mentioned most often across the sub-global assessments were land use change, climate change and variability, pollution, and invasive species. These drivers were seen to be only partially under the control of decision-makers at the particular scales assessed. Land use change comprises a whole range of processes, including urbanization (as in São Paolo or Portugal), encroachment on natural ecosystems by agriculture (as in Eastern Himalayas or Coastal British Columbia), and infrastructure works (as in Tropical Forest Margins or Caribbean Sea). A striking example of invasive species as a driver was found in the Caribbean Sea region, where dust blown from the Sahara across the Atlantic introduced new pathogenic bacteria which have been at least partially responsible for coral reef diseases in the last two decades.

Economic growth, structural change, and globalization were the most commonly identified indirect drivers of change. Their impacts on ecosystems were mediated by institutional and sociopolitical factors. Evidence from the sub-global assessments suggests that the impact of economic growth depends on a range of institutional settings and on the structure of growth itself. The economic changes of the 1990s introduced a market system in the Altai-Sayan ecoregion in Russia and Mongolia, for example, that resulted in a double impact: higher cashmere producer prices encouraged intensified herding at locations closer to marketplaces, causing overstocking in the surrounding areas. When Trinidad liberalized trade, local producer prices dropped, making local production of market crops unprofitable. The increases in transport that result from global trade are seen as a major indirect driver of increases in invasive species; the release of ballast water by ships in the Caribbean Sea, for example, introduced the Indo-Pacific green mussel *Perna veridis* to the region.

Drivers of change operate at different spatial scales and temporal rates of change, and there is no clear-cut relationship between a driver's spatial and temporal scales. Most drivers follow the general rule that the coarser the spatial scale over which the driver operates, the slower the process tends to be. However, the sub-global assessments identified a significant number of exceptions. For example, the São Paulo assessment mentions governance and legislation as a local, but slow driver. The same holds for soil degradation as a biophysical driver in Downstream Mekong. On the other hand, the assessment of San Pedro de Atacama, Chile, identified rapid worldwide changes of technology in the mining sector as an important driver. Argentine Pampas also identified fast technological change on the global, or at least the national, scale as an important driver.

Understanding drivers, their interactions, and the consequences for ecosystem services and human well-being is crucial for the design of effective responses. Although many responses target specific problems with ecosystem services, the nature of ecosystem change means that such responses can have unintended consequences in a system of multiple interacting drivers. Individual drivers may be difficult to influence without affecting other drivers; therefore intervening in the interactions among drivers is often a more direct way to achieve a desired outcome. This may also enable a more integrated and holistic approach to ecosystem management. The Kristianstad Wetlands assessment in Sweden found that this approach was adopted in the area through the implementation of adaptive management.

Drivers of ecosystem change often interact with one another in synergistic ways. Within the range of sub-global assessments, three major types of synergies between drivers were identified: processes that *trigger* each other, processes that *reinforce* each other, and processes that *constrain* each other. The introduction of EU policies in Portugal has triggered a high degree of dependency on decisions made at the European level, which might not be appropriate for local decision-making on the management of specific ecosystems and their services. Resettlement projects designed to release the pressures on the natural and social environment in the densely populated regions of coastal Southeast Asia have aggravated land use change (Tropical Forest Margins). The case when one driver constrains the action of another, might serve as a starting point for appropriate interventions. Institutional changes envisaged in the Stockholm Urban assessment in Sweden are seen as a possible action, as they are expected to constrain urban sprawl, which is a major driver of loss of green areas.

Drivers can be controlled to varying degrees by decision-makers. The degree of control is largely scale- and context-dependent. Factors such as legislation, international treaties, and governance structures can rapidly change and either mitigate or exacerbate the effects of drivers. In SAfMA Gariep, for example, the governance change that took place in South Africa in 1994 was rapid but affected a large area. Democratic governance had significant socio-economic implications for the greater southern African region.

The effect of drivers can change over scales and over time. For example a driver, endogenous at a certain scale, can become exogenous when local decision-making becomes subordinated to the implementation of national or regional goals. For example, in the Stockholm Urban assessment, infrastructure and green area management were under the control of local municipal authorities, but local authorities were superseded when national infrastructure plans were implemented.

7.1 Introduction

This chapter relies on various sources of information on the drivers of ecosystem change considered in the sub-global assessments, in particular the state of the assessment reports. In addition, information was collected throughout the process, in particular through two questionnaires filled in by the sub-global assessment teams (Q1, Q2), the two knowledge markets (KM1, KM2), and personal communication with key individuals. Because the sub-global assessments and their focus on ecosystem services are user-driven, the results presented here cover only some of what can be found in the scientific literature on this topic (for example, with respect to land use and land cover change; see Lambin et al. 2003). Nevertheless, the chapter seeks to draw as many lessons as possible from comparison of drivers across the sub-global assessments. A complete presentation of all the

individual drivers identified by each assessment can be found in the individual assessment reports available on the MA website (www.MAweb.org).

The chapter is organized as follows: The first section gives some background on the drivers of ecosystem change both within the MA global assessment and in the broader literature. The next section reports the findings on individual drivers in the sub-global assessments, their classification as direct or indirect and as exogenous or endogenous, and categories of drivers (economic, biophysical, etc.), giving particular emphasis to how drivers change across scales. The following two sections discuss driver interactions, first in terms of major processes of interaction and then with regard to non-linearity, thresholds, and crises. The final section explores the implications of these findings for ecosystem management, setting the stage for Chapter 9 on responses.

7.2 Background: Major Global Trends

The local and regional changes in ecosystems and their services in the various sub-global assessments operate against a background of global and regional-scale drivers. From the perspectives of most users of the sub-global assessments, these global and regional drivers are often considered exogenous, or beyond their control. This introductory overview is intended to outline major trends of those global drivers mentioned in the sub-global assessments, particularly climate change and economic globalization. It also seeks to elaborate on global trends of finer scale drivers discussed in the sub-global assessments, in order to frame the more detailed discussions of regional and local-scale drivers later in the chapter. This treatment is not meant to be comprehensive, and the reader is referred to MA *Scenarios,* Chapter 7, for a more detailed discussion.

Over the past two centuries, human activities have induced major changes in many ecosystems (for an overview, see Steffen et al. 2004; MA *Current State and Trends*). These changes have occurred at all scales, from local to global. Examples at the global level include perturbations of the world's climate system (Houghton et al. 2001), changes in stratospheric and tropospheric ozone concentrations, and changes in global patterns of transport of particles and pollutants (Hauglustaine and Brasseur 2001; Steffen et al. 2004). Changes at local scales are widespread and show a high degree of variability. Some of these local changes are reflected in the various sub-global assessments. We live on a human-dominated planet (Vitousek et al. 1997).

Population and economic growth, technological change, and changes in sociopolitical organization and institutions are key drivers of the massive increase in resource consumption. The nature of the interactions between these drivers (that is, how each of them dominates or is mediated by other factors, and the ability of natural systems to cope with pressures) varies across space and time. Nevertheless, these key changes constitute some major driving forces of environmental change.

Table 7.1 depicts changes in the world's population, production of food and energy, and economic output, between 1950 and 1993. Global population and global energy production have approximately doubled during this period, grain production has increased 2.7 times, world GDP has grown by a factor of 6, and global trade in merchandise by a factor of 20. Both per capita grain consumption and GDP per capita have increased in many places around the world, although significant exceptions exist. These global trends neglect regional differences in these factors, as well as differences in other factors and processes that may aggravate or attenuate them. Therefore, these gross increases give only a very general overview of the actual drivers of ecosystem change. Though efficiency improvements have been observed throughout history, the rate of economic growth has outpaced the rate of efficiency growth, thus leading to higher resource use and higher emissions of gases (carbon dioxide, nitrogen oxide, and to a lesser extent, sulfur dioxide) and increasing production of fluid and solid waste.

Table 7.1. Changes in Global Population, Food and Energy Production, and Economic Output, 1950–93 (Steffen et al. 2004 and MA *Scenarios,* Chapter 7)

	Grown by a factor of
Population (number of people)	2.2
Grain (total production in tons)	2.7
Energy (production)	2.0
Total world real GDP	6.0
Global trade in manufactured goods (volume, 1950–2001)	≈20
Consumption of N fertilizer (tons)	≈8

Human land use, agriculture in particular, is a key human activity altering ecosystems. Though grain production is still growing globally, the rate of growth is slowing. Meat production worldwide has grown at about 1.4% per annum over the last 40 years (FAOSTAT data 2004). Estimates of the expansion of cropland and pasture over the twentieth century range from 70% to 80% (Klein Goldewijk 2001). The sub-global assessment findings were consistent with these global observations.

Climate change is now considered by most scientists to be a significant driver of ecosystem change, and is expected to be an increasingly important driver in the future. According to the Intergovernmental Panel on Climate Change (2001), global mean temperature increased by between 0.4 and 0.8 degrees Celsius over the twentieth century. Although it is difficult to assign quantitative values to the contributions of the various factors influencing climate, it is now certain that anthropogenic interferences have contributed significantly to this rise in global mean temperature. Major reasons are the combustion of fossil fuels and land use change (particularly deforestation)—both of which add carbon dioxide to the atmosphere. Note that carbon storage is an important ecosystem service, which is assessed in a number of the sub-global assessments. (See Chapter 8.) The increase in global mean temperature plays out very differently in different regions of the world, and appears to be more pronounced in the northern high latitudes. In many regions of the world, this increase is accompanied by an

increase in precipitation, though some tropical regions have also seen decreases in precipitation. There is evidence that recent climate change has already brought about some specific changes in ecosystems (for example, a shift in the latitudes at which certain plants and animals are found, and a trend toward earlier greening in the northern high latitudes (Lucht et al. 2002; IPCC 2001)).

Though discussions of the effects of human activities on ecosystems via atmospheric processes have focused largely on climate change, emissions of other gases and particulate production by the burning of fossil fuels and biomass represent another major impact on the atmosphere, and ultimately on ecosystems and their services. The emission of sulfur dioxide, for example, is responsible for most of the acidification trends observable in the 1970s and 1980s in Europe and North America, and now in large regions in Asia. Sulfates also are major constituents of small, aerosol particles, which have a distinct effect on climate. Aerosols also have a direct impact on air quality, photosynthetic active radiation, and particle deposition (Heintzenberg 2004). Estimates of sulfur dioxide emissions since 1850 indicate an almost continuous increase, reaching about 70 million tons per year in the early 1990s. The most pronounced growth has occurred since the 1950s, when emissions were about 30 million tons per year. Due to increased pollution control efforts (for example, flue gas desulfurization and switching from high to low-sulfur coal), these trends have slowed or even reversed. Other environmentally damaging emissions from human activities are nitrogen oxides (from fossil fuel combustion and agriculture), dust (which affects climate and nutrient cycling), and heavy metals (including toxic substances like mercury).

Global biogeochemical cycles (that is, the water, carbon, nitrogen, and phosphorus cycles) are increasingly connecting social-ecological systems around the world. The global hydrological cycle is a natural component of the earth system that has been increasingly modified by humans. The atmospheric processes outlined above; the development of infrastructure that modifies rivers, lakes, or other wetlands; and changes in land use are changing patterns and/or levels of precipitation, evaporation, runoff, and river discharge throughout the world. According to some estimates, about 40% of the global runoff to the oceans is now intercepted by large dams, and some major rivers like the Yellow River in China and the Colorado River in North America discharge only a small fraction of their overall volume of water into the ocean (Vörösmarty et al. 1997; MA *Current State and Trends,* Chapter 8).

In 1990, the total amount of reactive nitrogen created by human activities was about 141 teragrams per year, which represents a nine-fold increase over 1890. At present, biological nitrogen fixation occurring in cultivated crops, synthetic nitrogen production, and fossil fuel combustion have become major sources of reactive nitrogen. (See MA *Scenarios,* Chapter 7.) Together with an increased input of phosphorus, this has had the positive impact of increasing food production at affordable prices, but at the same time has also had negative consequences for some ecosystem services. Effects range from contributing to the greenhouse effect by nitrous oxide through modification of tropospheric chemistry, to water pollution by nitrates and phosphates. As the latter is often the limiting factor in lake and river ecosystems, increased input of phosphorus can induce eutrophication, thus affecting services such as the provisioning of fresh water and lake fisheries.

Growth in international merchandise and financial trade over the past five decades has consistently been larger than global GDP growth. In the 1990s, growth rates in merchandise trade were three times that of world GDP—6% versus 2%, respectively (WTO 2004). Similar trends also hold for financial flows. For example, gross foreign direct investment grew from 2.7% of global GDP in 1990 to 6.0% in 2002 (WTO 2004). This ''economic globalization'' comes along with a broader range of interconnectedness, in the way of improved information and communication technologies, and a homogenization—but also spreading plurality—of cultures. Different views on the effect of economic growth on ecosystem change exist, some claiming an increasing negative impact whereas others see an increase in environmental protection and decreases in impacts in the course of economic growth. (For a more thorough discussion, see MA *Scenarios,* Chapter 7.)

7.3 Individual Drivers

This section highlights some driver-related issues within the MA conceptual framework (MA 2003), reflects on the process of assessing individual drivers in the sub-global assessments, and then presents major findings from the sub-global assessments in terms of:

- types of drivers (demographic, economic, sociopolitical, etc.);
- relationships between the two driver classifications across different spatial scales (exogenous and endogenous drivers versus direct and indirect drivers); and
- relationships between the spatial and temporal scales of drivers. (See also MA *Scenarios,* Chapter 7, for findings on drivers from the MA global assessment.)

7.3.1 Drivers within the MA Conceptual Framework

The MA conceptual framework (MA 2003) distinguishes between different types of driving forces that influence changes in ecosystems, their services, and therefore human well-being: direct and indirect drivers, and exogenous and endogenous drivers.

According to the conceptual framework, a *direct* driver unequivocally influences ecosystem processes. An *indirect* driver operates more diffusely, by altering one or more direct drivers. There are demographic, economic, sociopolitical, science and technology, cultural and religious, and physical and biological drivers. Important direct physical and biological drivers include changes in climate, plant nutrient use, land use, fires, diseases, invasive species, floods and droughts, and landslides. Understanding drivers and their interactions, which cause changes in ecosystems and their services (for example, between land use and droughts)

is essential to the design of interventions that enhance positive and minimize negative effects.

Decision-makers are agents of change, and their choices are influenced by a number of drivers. Their behavior in turn can lead to changes in these drivers. Drivers that cannot be altered by a decision-maker at a certain scale, but influence his/her decisions, are called *exogenous* drivers. *Endogenous* drivers, in contrast, are defined as the drivers that the decision-maker at a particular scale can influence (MA 2003). This distinction is important in order to understand who should take action in response to drivers, and how it should be done to generate the greatest effect. As will be discussed later in this section, findings from the sub-global assessments suggest that this distinction between exogenous and endogenous drivers is not always clear, as some drivers are under *partial* control of decision-makers.

Whether a driver is endogenous or exogenous depends in part on the spatial and temporal scales at which the decision-maker operates. At the local level, it is likely that more driving forces cannot be controlled by decision-makers, and are therefore exogenous. The MA conceptual framework states: ''As the time and space scales expand, more drivers become endogenous; that is, a different set of decision-makers has influence over the drivers'' (MA 2003; p. 87). For example, prices for a particular commodity are usually an exogenous factor that an individual farmer has little control over, while a national government can influence those same prices by regulating markets for the commodity. Drivers that are exogenous in the short run can also become endogenous over longer time periods. Population growth rate is a good example of this. Migration policies or measures to curb population growth rates can influence national population growth over a 20–50 year time horizon.

7.3.2 Individual Drivers in the Sub-global Assessments

A wide variety of methods was used to identify and assess the drivers of ecosystem change at sub-global scales. (See Table 7.2.) The choice of methods was influenced both by the different ecosystems and human systems assessed and by the different goals of each sub-global assessment. Some assessments followed the MA conceptual framework closely; examples include Southern Africa (Q1–SAfMA) and Portugal. Other sub-global assessments were already under way before joining the MA process (for example, Tropical Forest Margins, which emerged from a long-standing research initiative that had developed independently of the MA); these initiatives largely adopted the MA conceptual framework, but in some cases had to modify some components.

Not surprisingly, the most common method reported for identifying drivers was an analysis of published literature and data sources (KM1). More interesting was the importance of user engagement in the identification and assessment of drivers. The assessment methods can roughly be divided into three classes (information based on KM2):

- At one extreme, three assessments used local and traditional knowledge to identify and assess drivers. These three assessments were conducted at the local scale, where it is usually easier to identify the driving processes of change (Veldkamp and Lambin 2001), at least with respect to local-scale drivers or the local ''expression'' of coarser scale drivers.
- At the other extreme, six assessments relied mostly on reviews of scientific literature and/or data analyses to identify and assess drivers. Some of these assessments (for example, Altai-Sayan and Western China) involved large areas where detailed local knowledge would not have been appropriate given the coarse scale of assessment.
- The rest of the assessments tried to reach a balance between scientific and nonscientific information sources.

Table 7.3 presents a broad classification of the scientific perspective of 20 sub-global assessments analyzed.

A common thread in many sub-global assessments was the lack of information needed to identify drivers and evaluate conditions and trends in ecosystem services, independently of one another. (See also Chapter 8.) In seven state of the assessment reports, it is clearly stated that there was not enough information to adequately assess the drivers, conditions, and trends of selected ecosystem services and related aspects of human well-being. Some assessments (for example, Northern Range in Trinidad) worked mostly with qualitative data, mainly due to gaps in quantitative information (Keisha Garcia, personal communication). Many assessments (for example, India Local and Sinai) tried to fill the information gaps using traditional and local knowledge; in these cases, the integration of different knowledge systems became particularly important. (See Chapter 5.)

Most sub-global assessments did not find it difficult to distinguish between direct and indirect drivers. However, the categorization of exogenous and endogenous drivers was more novel to many (from KM2). Several sub-global assessments (Caribbean Sea, San Pedro de Atacama, Papua New Guinea, Portugal) that categorized the factors influencing ecosystem change in their area according to the degree of controllability were able to apply the concept without much difficulty. In general, their definitions of ''controllability'' were analogous to the concept of whether a driver is endogenous or exogenous, and therefore fit well with the MA conceptual framework. The assessment in Papua New Guinea even clearly distinguished the usefulness of the different driver categories as an analytical tool, stating that ''the distinction between direct and indirect drivers is made from the point of view of scientists, while the distinction between internal (endogenous) and external (exogenous) drivers is made from the point of view of the manager or decision-maker'' (PNG).

Nevertheless, not all sub-global assessments used the concept of controllability of drivers at different scales as a analytical tool to discuss policy options with their stakeholder groups. The degree to which a sub-global assessment's work had been completed made an enormous difference in the understanding of the drivers assessed. Assessments in the preliminary stages typically included a list of broad categories of drivers in their status reports that were heavily influenced by the availability of data, and may not therefore have represented the full scope of drivers and their relative importance. Some also found it difficult to

Table 7.2. Summary of Methods Used to Identify and Assess Drivers of Ecosystem Change in Sub-global Assessments

Sub-global Assessment	Methods of Driver Identification and Assessment
Altai-Sayan	mostly from analysis of existing literature and data sources
Tropical Forest Margins	meta-analysis of case studies reported in the literature using LUCC framework
San Pedro de Atacama	review of current conditions and main trends, recent environmental impact studies of projects in the region, development initiatives in the region; through direct enquiries with users
Caribbean Sea	literature review, sending questionnaires to experts, drawing causal diagrams during focus group discussions at workshops, and in a few cases, analysis of statistics (e.g., hurricane frequency, tourism) and GIS (e.g., fisheries).
Colombia	review of existing literature and data sources; GIS analysis
Bajo Chirripó	review of existing literature and data sources, workshops, interviews, and a strong emphasis on participatory methods
India Local	review of existing literature; workshops and group discussions at different scales; emphasis on participatory methods
India Western Ghats	formal and informal interviews with a variety of actors (politicians, civil society, private institutions, communities); when available, secondary data used to complement primary data
Vilcanota	early stages involved fieldwork to identify preliminary driving forces, and conditions and trends, which were discussed at workshops with community members to select the main drivers; strong emphasis on participatory methods
Papua New Guinea	expert review of existing literature and datasets at national and local scales, supplemented by some stakeholder interviews at the local scale
Laguna Lake Basin	used the IPCC approach, which relies mainly on the assessment of existing literature
Portugal	workshops involving the assessment team and users; expert judgment (these experts undertook a literature review independently)
SAfMA	diversity of methodologies, with each component assessment using different methods to identify drivers; strong emphasis on participatory methods at the community and basin levels (Gariep, Zambezi, and Gorongosa-Marromeu basins); as the scale of analysis became coarser, the identification of drivers relied more on the review of existing literature and data sources, as well as quantitative modeling
São Paulo	field experience and analysis of existing literature and data sources used to identify drivers; these preliminary findings were presented and discussed at workshops with stakeholders and scientists to select the most important drivers from the preliminary list; after the drivers were chosen, scientists wrote a three-page summary giving specific details of the chosen drivers
Sinai	field visits used most frequently to identify and assess drivers; complemented by literature review and consultations with local people, stakeholders, and scientists
Sweden KW	drivers identified using literature review, semi-structured interviews with different stakeholders, and documented land use patterns since the 19th century; strong emphasis on understanding the social context (e.g., social capacity, social networks)
Sweden SU	drivers identified through review of existing literature and data, GIS analysis, gap analysis modeling, statistical trends, natural resource inventories, field data, and interviews with stakeholder groups; emphasis on stakeholder participation
Northern Range	drivers identified and assessed through workshops and meetings of collaborators (Advisory Group, Steering Committee, Working Groups) based on studies where they exist (e.g., study of carrying capacity for tourism on the North Coast of the island of Trinidad) and on expert knowledge
Downstream Mekong	interviews, workshops, review of existing literature and data, and GIS analysis
Western China	review of existing literature and data sources; quantitative modeling

conceptualize the interactions among drivers using formal instruments like diagrams. As the assessment process advanced, the understanding of what the specific drivers were, how they change over time, and how they interact, became clearer for the assessment teams.

7.3.3 Driver Categories

The sub-global assessments examined the full range of drivers outlined in the MA conceptual framework and ranked them according to their importance within their particular context. Major groups of drivers are discussed in the following subsections. The absence of particular drivers (for example, there is almost no indication of religious drivers) does not necessarily imply that these drivers do not play a role in those areas.

Figure 7.1 in Appendix A depicts the broad indirect drivers identified by the sub-global assessments at regional and national scales, and reflects the range of different approaches to the assessment of drivers. The information in the map comes from questionnaires, knowledge markets, and state of the assessment reports. Some assessments focused on a single driver, while others assessed a broad range of drivers.

7.3.3.1 Demographic Drivers

Population growth is mentioned as the most dominant indirect driver in the Downstream Mekong, Colombia, Sinai,

Table 7.3. Emphasis of the Scientific Perspective on the Identification and Assessment of Drivers

Perspective	Examples of Sub-global Assessments
Strong emphasis on the user/community identification of drivers	Bajo Chirripó, India Local, Vilcanota
Balance between the user/community identification of drivers assessment drivers through data analysis or literature reviews	San Pedro de Atacama, Caribbean Sea, PNG, Portugal, SAfMA, São Paulo, Sinai, Sweden KW, Sweden SU, Northern Range
Strong emphasis on data analysis or literature review	Altai-Sayan, Tropical Forest Margins, Colombia, Laguna Lake Basin, Downstream Mekong, Western China

and Eastern Himalayas assessments. In these areas, population growth is seen as a major cause of increasing demand for food, fuelwood, fodder, and other ecosystem services. National statistics on population growth suggest relatively high annual population growth rates in these locations in comparison with those sub-global assessment areas where population growth is not considered a dominant indirect driver (for example, Portugal, Northern Range, and Coastal BC). Where population growth was assessed to be a key driver, people often faced additional challenges including low economic growth and limited means of income generation apart from the utilization of local ecosystem services. (See Figure 7.2.)

Urbanization is frequently mentioned as a major demographic driver (Caribbean Sea, Northern Range, Sinai, SAfMA, Portugal, São Paulo). In most of these regions, urbanization in coastal areas was identified as having a more significant impact on ecosystem change than in inland areas, suggesting that the global increase of urban regions in coastal areas is going to be a major driver of ecosystem change in the near future.

7.3.3.2 Economic Drivers

All sub-global assessments identified economic drivers as important, although in different ways. In some regions, the driver was simply *economic growth*. A more comprehensive picture emerges if one considers how developments in particular economic sectors have profound impacts on ecosystem change. Key examples from sub-global assessments include:

- *Exploitation of natural resources, in particular forestry, fishing and other inshore marine resources*. The Lihir assessment in Papua New Guinea (PNG–Lihir) mentions increasing fishing pressure as an important example. In this region and also in the Caribbean Sea, increased fishing by international trawlers is putting increased pressure on marine fisheries in addition to fishing by local or regional fishermen. In PNG–Lihir, the national policy component of a sectoral resource management regime (like the fisheries regime) appears as an external imposition or constraint to members of a coastal community; but resource management decisions taken by members of traditional communities within their own domains are barely subject to any control by national government agencies (PNG–Lihir).
- *Tourism*. In three assessments (Caribbean Sea, Portugal, and Sinai), tourism was seen as an opportunity for income generation. At the same time, local people must also bear the often negative environmental side-effects of tourism. The Caribbean Sea is a good example of where there are only limited benefits of tourism for the local people in terms of income opportunities.
- *Mining*. Besides having direct ecosystem impacts, for example, through land use change, water withdrawal, or release of pollutants, mining can also have positive impacts by providing income for the local population (São Paulo, San Pedro de Atacama).
- *Mega-projects*. Examples include agricultural projects that aim to produce cash crops and provide income and economic growth to the region (Sinai) and the building of large dams (Eastern Himalayas, Coastal BC). The benefits for local people are often rather limited when compared to the costs.
- *External events*. A crisis in the global coffee market resulted in a shift toward less sustainable activities such as cattle grazing in the coffee-growing region of Colombia.

Thus economic growth was seen as a two-edged sword: though it often brings benefits that improve human well-being, it may also have other consequences that outweigh the benefits if not accompanied by appropriate institutional developments with regard to environmental protection. The issue, however, is not about economic growth per se, but rather about having the right institutional frameworks so that growth might occur equitably and sustainably.

7.3.3.3 Sociopolitical Drivers

Governance and policy structure and change are mentioned throughout most of the sub-global assessments, although they refer to changes in a diverse set of institutional settings and circumstances. Governance and policy changes have consequences for ecosystem services in three major ways:

- *Introduction of new economic regimes, possibly related to changes in political systems*. For example, in southern Africa, a trend toward democratization and increased participation can be observed in some countries, yet opaque and corrupt governments remain in power in others (Scholes and Biggs 2004). The trend toward democratization is sometimes accompanied by moves toward more open, market-oriented economies (for example, SAfMA and Altai-Sayan). In Portugal, the introduction of EU policies has led to major changes in the agricultural production system.
- *Co-operation or competition among decision-makers over resource management, particularly in open access or common property regimes*. The Caribbean Sea provides a good example of this, where the pursuit by individual national governments of economic opportunities based on Caribbean Sea resources have had the effect of forcing down economic rents as well as standards for environmental protection (Keisha Garcia, personal communica-

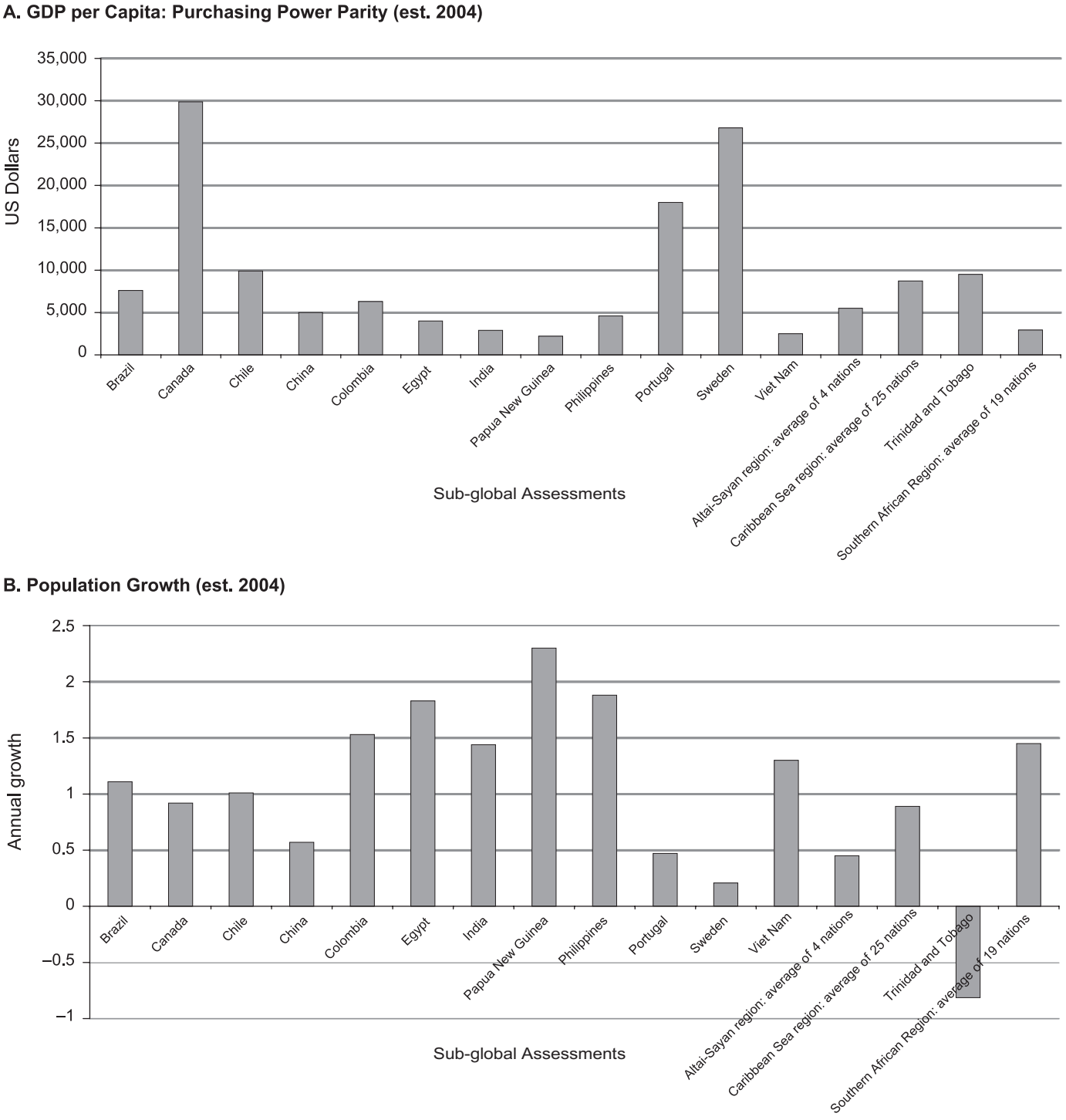

Figure 7.2. General Overview of Population Growth and Gross Domestic Product per Capita in Selected Countries with Sub-global Assessments (World Factbook 2004)

tion). This competition can also be observed at finer scales, as in the Stockholm urban assessment where individual municipalities compete with one another to secure construction investments and the establishment of enterprises (Sweden SU). This competition has often sub-optimal effects for regional green area management and for important ecosystem services (Jakob Lundberg, personal communication).

- *Failed centrally planned projects for improving the living conditions of local communities and people*. This was observed in India Local and appears to be particularly important for poor, rural areas. As noted in the literature (for example, McCully 1996), the benefits of these projects, even if they succeed, are often not fully received by the local people (see also discussion later in this chapter).

7.3.3.4 Science and Technology

Particularly important as a driver is the introduction of new technologies. Here, ''new'' does not necessarily imply an emergent or newly developed technology, but may simply

mean a technology new to the region or locality being considered. The introduction of new technologies is closely related to economic drivers, as new industrial or economic activities in a region often bring new technologies. In other cases, it is the *substitution* or *extension* of existing technologies that induces ecosystem change (for example, the introduction of new cultivars in agriculture, new harvesting technologies, irrigation development, and genetically modified organisms).

The sub-global assessments suggest that technological change has both positive and negative effects: on the one hand it can increase human well-being by increasing the productivity or efficiency with which ecosystem services are obtained, on the other hand, it can increase pressure on ecosystems; examples include overfishing (Caribbean Sea, PNG–Lihir) or making new land available (housing in the steep hills of the Trinidad Northern Range). In some places, as in southern Africa, it is a lack of technology or infrastructure that induces pressure on ecosystems (Biggs et al. 2004).

7.3.3.5 Cultural and Religious Drivers

Cultural and religious drivers include changes in lifestyles (for example, from traditional to modern), values and norms (in particular with respect to the environment), and knowledge and education.

Changes in traditional systems and lifestyles were seen in the sub-global assessments to be a major driver of ecosystem change. For example, in the Mekong wetlands of Vietnam, increased demand for ecosystem services was found to be due to changes toward a more ''market-oriented lifestyle'' (Downstream Mekong). Changes in the Atacameños lifestyle in Chile, from traditional to more modern ways of living, and the effects on ecosystems, are illustrated by a comment from an inhabitant of the region:

> *''Now trickle irrigation is the fashion, so the agricultural engineer comes with a project and says: we need pvc, pvc trickler, engines, sulfates, etc., and estimates production over five years. Of course you get big fruit the first year, but by the fifth the soil is no good, it is exhausted. The engineer leaves after the five years are up.'' (San Pedro de Atacama, p.23)*

In two other assessments, the lack or loss of environmental awareness is mentioned as a driver of change (Northern Range, São Paulo). Northern Range mentions some improvements due to public education, but it is not yet widespread enough to alter human impacts on the Northern Range of Trinidad. There is a degree of stewardship and appreciation of sustainability issues among community and religious groups who are directly affected by the deterioration of the environment, and who are becoming more organized and articulate. Yet these trends have not yet reached a critical level of influence on society as a whole.

Examples can be found in the sub-global assessments where environmental awareness does lead to more sustainable behavior. In the Kristianstad Wetlands assessment in Sweden, a new generation of technicians with a worldview more open to nature conservation is working with urban planners to improve ecosystem health (Sweden KW). In the local community assessments in the Gariep basin in South Africa, it was found that religion serves as a starting point for responses, as it can serve as motivation for forming local institutions to deal with uncertainty (SAfMA Gariep).

7.3.3.6 Physical and Biological Drivers

One driver mentioned in a substantial number of sub-global assessments was the introduction and/or invasion of alien species. The Caribbean Sea assessment, for example, reports on research demonstrating that dust blown across the Atlantic Ocean from the Sahara brings along new microbes which directly affect coral reefs in the Caribbean—a particularly illuminating example of the effect of global processes on local environments. In other sub-global assessments, the introduction of alien species is mostly a by-product of increased national or international trade or the introduction of new technologies. The introduction of new cultivars has occasionally introduced new pests into the croplands of Papua New Guinea (PNG). In one of the sub-regions investigated in the Coastal British Columbia assessment, introduced deer have modified the forest more extensively than timber industry activities. Introduced raccoons and rats have destroyed seabird colonies. Beavers have reduced willow and wild apple populations and heavily modified lowland stream systems, altering stream courses and joining lakes that have been isolated since glaciation. The deer, raccoon, and beaver introductions were deliberate, for game and fur, while the rats came accidentally (Coastal BC).

Climate change and variability appear as a driver in the sub-global assessments in a variety of ways. Local climate change due to urbanization, resulting from the so-called urban heat island effect, has a measurable impact on ecosystems within the São Paolo urban region (São Paolo). In some instances, global climate change is reported to have directly caused recent ecosystem change (examples include Caribbean Sea and, to a lesser extent, SAfMA and Western China). Within the southern Africa region and throughout China, the recent trend of global warming is confirmed in many places. Nevertheless, a large degree of uncertainty still prevails with regard to both the causes and impacts of these changes in climate. In other assessments, the recent trends of climate change and the prospects of further warming in the future are seen as major drivers of future change, either directly or indirectly. In Papua New Guinea, for example, future climate change is seen as a major expected environmental problem, due to potentially increased frequencies and intensities of tropical cyclones, and the direct impacts of temperature increase and sea level rise (PNG). The Tropical Forest Margins assessment reports that climate change (present and future) has induced difficulties in crop planning. The prospect of future climate change has also elicited adaptive actions that have already had an impact on ecosystems, for example, in the Kristianstad wetlands where river embankments were raised (Sweden KW).

Several sub-global assessments identified the occurrence of climate-related extreme events as major direct drivers. Shifts in fire regimes were observed in Portugal and the forest ecosystems of the Altai-Sayan ecoregion. In the Ca-

ribbean Sea assessment, there is some indication that tropical cyclones are increasing in frequency, yet this increase is still within the natural range of variability of the last century. Given the difficulty of relating short-term trends in extreme events to climate change, it is not possible to attribute these drivers to anthropogenic climate change. Nevertheless, the increase in tropical cyclones in the region has induced a shift in yachting toward the south, which is correlated to infrastructure development on the north coast of Trinidad, with some implications for local ecosystems (Northern Range).

Overall, physical and biological drivers are mainly seen as increasing the pressures on ecosystems, resulting in decreases in the provisioning services of ecosystems.

7.3.4 Spatial Scales and Driver Classification

This section discusses the classification of drivers as being direct or indirect, and endogenous or exogenous—first in terms of particular spatial scales and then in terms of patterns across scales. In order to do this, the drivers found in individual assessments have been assigned to one or several of the following spatial scales: local, sub-national, national, regional, and global. There are, in principle, two aspects of scale to consider: the scale at which a driver operates and the scale at which the driver can be changed through human influence. Here, the focus is on the scale at which a driver can be changed. The information on scales has been obtained either from the state of the assessment reports, the knowledge markets, or answers to questionnaires. All data have been compiled into a single data file that can be downloaded from the MA website; the data served as a basis for the tables presented in this chapter and for the statistical analysis.

A total of 241 drivers were identified across all of the sub-global assessments. Of these, a classification of spatial scale was obtained for 213, and a classification of speed was obtained for 108. Many drivers were classified as belonging to more than one spatial scale. For 178 drivers, classification as direct/indirect and exogenous/endogenous was also done.

7.3.4.1 Drivers at the Local Scale

Local scale drivers found in the sub-global assessments are shown in Table 7.4, organized into a matrix of direct/indirect versus exogenous/endogenous. The most frequently mentioned direct driver was land use and land cover change, and it is in all instances classified as endogenous. In general, all endogenous drivers at the local scale appear to be related to management activities (that is, they can be controlled by changes in decision-makers' choices on how to manage local ecosystems and their services). An encouraging example is the South African initiative *Working for Water,* where local management decisions aimed to reduce the negative impact that the introduced Eucalyptus tree has had on the water table (Biggs et al. 2004).

As expected, exogenous drivers are more varied, ranging from natural phenomena (for example, climate) to economic policy and infrastructure development. In some instances, drivers are classified as being both endogenous and exogenous. This hints at the high degree of complexity when it comes to questions about control over drivers. Decision-makers at the local level may perceive some drivers as being under their *partial* control, as in the case of São Paulo, where urban growth and real estate speculation are seen as only partially controllable (São Paulo). This indicates that the concept of endogenous versus exogenous drivers introduced in the MA conceptual framework is sometimes not strictly applicable.

The table also shows that there are more endogenous than exogenous drivers identified at the local scale. This pattern also carries through coarser scales up to the national level. This is somewhat contrary to what is suggested in the MA conceptual framework (discussed further below in the context of emerging patterns).

In general, there are more direct than indirect drivers at the local scale. This probably relates to the perception that most drivers at this scale are unequivocally acting on ecosystems and causing change (MA 2003). Some anthropogenic drivers appear to be direct, and are mostly economic and technology-related. These drivers are also largely related to harvesting, management, and exploitation activities (for example, the intensification of harvesting activities in PNG–Lihir or the use of external inputs for agriculture in the Argentine Pampas).

7.3.4.2 Drivers at the Sub-national Scale

For drivers at the sub-national level, a picture somewhat similar to the one at the local scale emerges. (See Table 7.5.) Land use change, external input use, and harvesting are again seen as major direct drivers. However, there are more exogenous, indirect drivers than at the local scale, in particular in relation to endogenous, indirect drivers—perhaps because drivers that are exogenous at sub-national or local scales are actually perceived as homogenous across micro-regions and as not having a further variability across local scale communities. For example, economic growth as an indirect sub-national scale driver (for urban sprawl) relates more to growth in the entire Stockholm metropolitan region than to growth in the direct neighborhood of the Stockholm National Urban Park, the actual assessment area (Sweden SU).

7.3.4.3 Drivers at the National Scale

Most sub-global assessments dealt with national drivers and thus the largest number of drivers was assessed at this scale. (See Table 7.6.) Some drivers that were exogenous at the local scale became endogenous at the national scale. For example, in Viet Nam, legislation is an exogenous driver at the local scale but policies and regulatory management are endogenous at the national scale (Downstream Mekong). In Papua New Guinea, sectoral resource management is exogenous in the local-level assessment (PNG–Lihir) and endogenous in the national-level assessment (PNG).

Due to the strong link between the levels of decision-making and whether a driver is endogenous or exogenous, the classification of a driver as being exogenous or endogenous can actually change when the political or normative

Table 7.4. Drivers of Ecosystem Change at the Local Scale. Drivers are classified as being direct or indirect, and exogenous or endogenous. Note that there are some drivers which are classified as exogenous *and* endogenous at the same time (for example, loss of traditional knowledge in Bajo Chirripó).

	EXOGENOUS	ENDOGENOUS
DIRECT		
	Argentine Pampas: disease, pest, and weed outbreaks; climate	**Argentine Pampas:** changes in land use/land cover; external input use; technology application
	Laguna Lake Basin: lake water level; land cover change	**Laguna Lake Basin:** land use change
	PNG–Lihir: tectonic disturbances; freak weather events with localized impacts	**PNG–Lihir:** intensification of harvesting activities; deforestation for expansion of food-cropping; industrial exploitation of inshore marine resources; discharge of domestic waste material; deliberate introduction of exotic species or varieties
	São Paulo: air pollution; industrial deconcentration	**São Paulo:** urban waste; mining
	India Local: legislation	**Bajo Chirripó:** agrodiversity loss
	SAfMA: climate	**Caribbean Sea:** aquaculture
	Sweden SU: invasive species	**Eastern Himalayas:** agricultural technology
	Downstream Mekong: legislation	**San Pedro de Atacama:** waste disposal
		Sinai: ground water pollution; soil degradation
		Western China: land use change; climate change; demography
		Bajo Chirripó: loss of traditional knowledge
		India Local: NWFP ownership
		Laguna Lake Basin: introduction of exotic species; technology introduction; pollution
		São Paulo: urban growth and real estate speculation; infrastructure works; vegetation clearing and extraction
INDIRECT		
	PNG–Lihir: sectoral resource management (national policy); price of commodity exports, imported food and fuel; scientific and technological change in agriculture, energy, and water supply	**PNG–Lihir:** volume of human migration across community domains; change in indigenous resource management regimes; devaluation of local customs and customary leadership; destabilisation of customary tenure systems; loss of agricultural knowledge
	SAfMA: demography; regional integration	**SAfMA:** governance; growth rate, wealth distribution, foreign investment; sociocultural values; poverty; infrastructure
	São Paulo: insufficient environmental awareness	**São Paulo:** land regulation; governance limitations
	India Local: economic demand (e.g., fish, trees); institutions (e.g., Forest Department)	**Downstream Mekong:** soil degradation
	Laguna Lake Basin: markets and consumption	**San Pedro de Atacama:** Atacameños' lifestyle changes
		Sinai: urbanization
		SAfMA: large-scale interventions

situation in a society changes. Before the end of apartheid, South African trade was largely limited by sanctions imposed by foreign governments; agricultural policy decisions were made at the national level and thus the driver was endogenous. With the end of apartheid, South Africa reentered world agricultural markets and its national agricultural policy is now influenced by international transactions (Bohensky et al. 2004).

7.3.4.4 Drivers at the Regional Scale

A smaller number of regional drivers were identified in the sub-global assessments than were identified at finer scales. (See Table 7.7.) This was probably due to the relatively small number of assessments at the regional scale. However, at this scale endogenous drivers are no longer dominant, at least in terms of numbers.

Anthropogenic direct drivers were mainly related to technologies and intensity of harvesting which appear to be, at least in the regions covered by the sub-global assessments, controllable at the national level or below, but not at regional or even global scales. In this respect, national governments are still seen as having the strongest role in decision-making when it comes to influencing the direct drivers of ecosystem change.

7.3.4.5 Drivers at the Global Scale

Few sub-global assessments addressed global drivers, as might be expected given the focus of the sub-global assessments on

Table 7.5. Drivers of Ecosystem Change at the Sub-national Scale. Drivers are classified as being direct or indirect, and exogenous or endogenous.

	EXOGENOUS	ENDOGENOUS
DIRECT		
	Argentine Pampas: climate	**Argentine Pampas:** external input use; technology application
	Altai-Sayan: climate warming	**Altai-Sayan:** fire; recreation; forestry; water use; waste discharge
	São Paulo: industrial deconcentration	**São Paulo:** urban waste; mining
	Sinai: external inputs	**Sinai:** land use pattern
	India Local: legislation	**Laguna Lake Basin:** wetland rice cultivation; pollution; deforestation
	SAfMA: climate	**San Pedro de Atacama:** changes in land use patterns
	Downstream Mekong: legislation	**Sweden KW:** land use changes; increased flooding; eutrophication; urban sprawl
		Sweden SU: green area loss
		Tropical Forest Margins: agricultural expansion; infrastructure development; wood extraction
	Argentine Pampas: disease, pest, and weed outbreaks	
	San Pedro de Atacama: water consumption	
	India Local: NWFP ownership	
	São Paulo: urban growth and real estate speculation; infrastructure works; air pollution; vegetation clearing and extraction	
INDIRECT		
	SAfMA: demography	**SAfMA:** governance; economic growth, wealth distribution, foreign investment; sociocultural values; poverty; infrastructure
	São Paulo: insufficient environmental awareness	**São Paulo:** land regulation; governance limitations
	Sinai: economic factors	**Sinai:** population growth
	Sweden KW: EU Common Agricultural Policy influence on land use changes; competition between municipalities; intensive agriculture	**Sweden KW:** social capacity for ecosystem management; changes in forestry management
	Sweden SU: economic growth	**Sweden SU:** population growth; lack of inter-municipal coordination
	Altai-Sayan: economic transition and policy	**Western China:** economic policy
	Laguna Lake Basin: industrialization; population change and settlements	
	San Pedro de Atacama: economic growth	
	Tropical Forest Margins: economic policy and institutions; technology; culture; demography	
	SAfMA: large-scale interventions	

sub-global scales. Moreover, global scale drivers were seen to be exogenous by most of the sub-global assessments given that they were largely beyond the control of individual decision-makers at sub-global scales. (See Table 7.8.)

7.3.4.6 Emerging Patterns

Based on Tables 7.4 through 7.8 and some cross-cutting analysis, some conclusions on the directness of drivers, and whether they are exogenous or endogenous, can be drawn, depending on the scale of the drivers. Overall, the number of direct drivers assessed was slightly higher than the number of indirect drivers (53% versus 47%). Most of the direct drivers were biophysical (66%), with economic drivers (24%) dominating the remainder. The fact that a significant number of anthropogenic drivers were classified as direct is somewhat contrary to the MA conceptual framework, where biophysical drivers are seen as being dominant among direct drivers. Direct economic drivers mostly relate to harvesting activities; examples include deforestation (Laguna Lake Basin) and fishing (Caribbean Sea, PNG).

Anthropogenic drivers were predominant among the indirect drivers. In particular, economic drivers (35%) and sociopolitical drivers (27%) were mentioned. A number of biophysical drivers were also identified (9%). The Northern Range assessment in Trinidad reveals an interesting example of how changes in weather patterns on the scale of the entire Caribbean Sea constitute an indirect driver. Due to an increase in the frequency of tropical cyclones (the indirect driver) in the 1990s, the insurance rates for owning a yacht in one of the northern islands in the region increased. This led to increased demand for marinas on the northern coast of Trinidad, which is still seen as relatively protected from

Table 7.6. Drivers of Ecosystem Change at the National Scale. Drivers are classified as being direct or indirect, and exogenous or endogenous.

	EXOGENOUS	ENDOGENOUS
DIRECT		
	Altai-Sayan: climate warming	**Altai-Sayan:** fire; recreation; forestry; water use; waste discharge
	Caribbean Sea: Ship-borne species introduction	**Caribbean Sea:** changes in coastal land and sea use; land-based pollution; marine pollution
	PNG: global warming and periodic droughts; accidental introduction or invasion of exotic species; land use or resource management by traditional communities	**PNG:** discharge of waste by industry; industrial exploitation of inshore marine resources
	Downstream Mekong: legislation	**Downstream Mekong:** infrastructure and urban development
	India Local: legislation	**San Pedro de Atacama:** changes in land use patterns
	SAfMA: climate	**Laguna Lake Basin:** pollution
		Portugal: land use changes; exotic species
		Northern Range: land conversion
		Tropical Forest Margins: agricultural expansion; infrastructure development; wood extraction
		San Pedro de Atacama: water consumption
		Portugal: fire regime
		Downstream Mekong: land use change
INDIRECT		
	PNG: sectoral resource management (global policy); world market prices for exports and imports; technical innovations in agriculture, energy, and water supply; natural population increase	**PNG:** macroeconomic and economic development policies; sectoral resource management (national policy); general decline in government services to rural areas; industrial exploitation of resources outside the coastal zone
	SAfMA: demography	**SAfMA:** governance; economic growth, wealth distribution, foreign investment; sociocultural values; infrastructure
	Northern Range: changing weather pattern; culture and behavior	**Northern Range:** economic forces; governance; urbanization; demand for recreation
	Downstream Mekong: population change; technological development; war	**Downstream Mekong:** economic pressure; policies and regulatory management
	Western China: population change; economic development; labor change; environmental policies	**Western China:** economic policy
	Altai-Sayan: economic transition and policy	**Portugal:** land tenure
	Argentine Pampas: socioeconomic policies; public and private trade strategies; market fluctuations; demographic patterns; technology supply	
	Bajo Chirripó: political corruption	
	Laguna Lake Basin: industrialization; population change and settlements	
	San Pedro de Atacama: economic growth	
	Tropical Forest Margins: economics; policy and institutions; technology; culture; demography	
	Portugal: tourism; economic growth; population distribution and migration; environmental legislation and attitudes	
	SAfMA: large-scale interventions	
	Downstream Mekong: tourism	

cyclones. The development of the corresponding infrastructure (the direct driver) brought about ecosystem changes in the region (Northern Range).

In an analysis across the scales of drivers, some general patterns emerge, in particular with regard to the relationship between direct and indirect drivers on the one hand, and exogenous and endogenous drivers on the other. (See Figure 7.3.) The overall number of direct drivers decreases as scales get coarser, that is, drivers act in the clearest ways at finer scales. This is in line with the observation that most direct drivers are related either to biophysical impacts or to management activities that take place at the scale of the ecosystem itself. With regard to indirect drivers, the number of drivers is highest at the national scale, because drivers that act diffusely are not seen as directly related to the scale of the ecosystem, but more related to the scale of adminis-

Table 7.7. Drivers of Ecosystem Change at the Regional Scale. Drivers are classified as being direct or indirect, and exogenous or endogenous.

EXOGENOUS	ENDOGENOUS
DIRECT	
Caribbean Sea: climate change: hurricanes; alien species from Amazon/ Orinoco	**Caribbean Sea:** fish harvesting technology
SAfMA: climate	**India Local:** dependence on one single product
INDIRECT	
Caribbean Sea: trade: international shipping	**Caribbean Sea:** population growth; coastal urbanization; trade; regional coordination and governance
SAfMA: demography	**SAfMA:** governance; economic growth, wealth distribution, foreign investment; sociocultural values; infrastructure; regional integration
Argentine Pampas: socioeconomic policies; public and private trade strategies; market fluctuations; demographic patterns; technology supply	
Northern Range: changing weather pattern	
Portugal: environmental legislation and attitudes; EU Common Agricultural Policy and global markets	
SAfMA: large-scale interventions; science and technology	

Table 7.8. Drivers of Ecosystem Change at the Global Scale. Drivers are classified as being direct or indirect, and exogenous or endogenous.

EXOGENOUS	ENDOGENOUS
DIRECT	
Caribbean Sea: climate change: sea temperature; species introduction: Sahara dust	
INDIRECT	
SAfMA: economic growth, wealth distribution, foreign investment	**SAfMA**: international trade regime
Argentine Pampas: socioeconomic policies; public and private trade strategies; market fluctuations; demographic patterns; technology supply	
San Pedro de Atacama: technological changes in mining	
Northern Range: changing weather patterns	
Downstream Mekong: climate change	

trative organization. This is supported by the fact that, by far, most indirect drivers are anthropogenic.

Most identified direct drivers—from local to national scales—are endogenous. At finer scales, many identified drivers are perceived as being at least partially controllable. At coarser scales, the perception of controllability fades. The limited controllability of regional resource management policies in the Caribbean is a good example of this.

Most indirect drivers at the national scale are exogenous, whereas at other scales indirect drivers are more evenly exogenous or endogenous. This is related to the fact that many decision-makers involved in ecosystem management at different scales perceive drivers at the national scale to be outside of their control. For example, the structure and development of the economy might well be under the control of national decision-makers, but may not be perceived in this light by an individual official inside the agriculture ministry. Unfortunately, no good example to support this hypothesis can be found among the sub-global assessments.

A number of sub-global assessments identified specific drivers as being exogenous *and* endogenous at the same time (for example, the loss of traditional knowledge on the local scale in Bajo Chirripó). In being assigned to both categories, it appears that *some* control over the driver is attributed to the decision-maker at the specific scale, although it is not seen as under the decision-maker's *total* control. The specification of drivers as exogenous or endogenous also depends on the political and institutional structures of a given society.

7.3.5 Driver Scale and Dynamics

This section focuses on the relationship between the spatial and temporal scales of drivers analyzed in the sub-global assessments, distinguishing between two aspects of a driver's temporal scale: the speed at which the driver operates and the speed at which the driver can change. A similar distinction is made between these two aspects of a driver's spatial scale. Though not many assessment teams distinguished be-

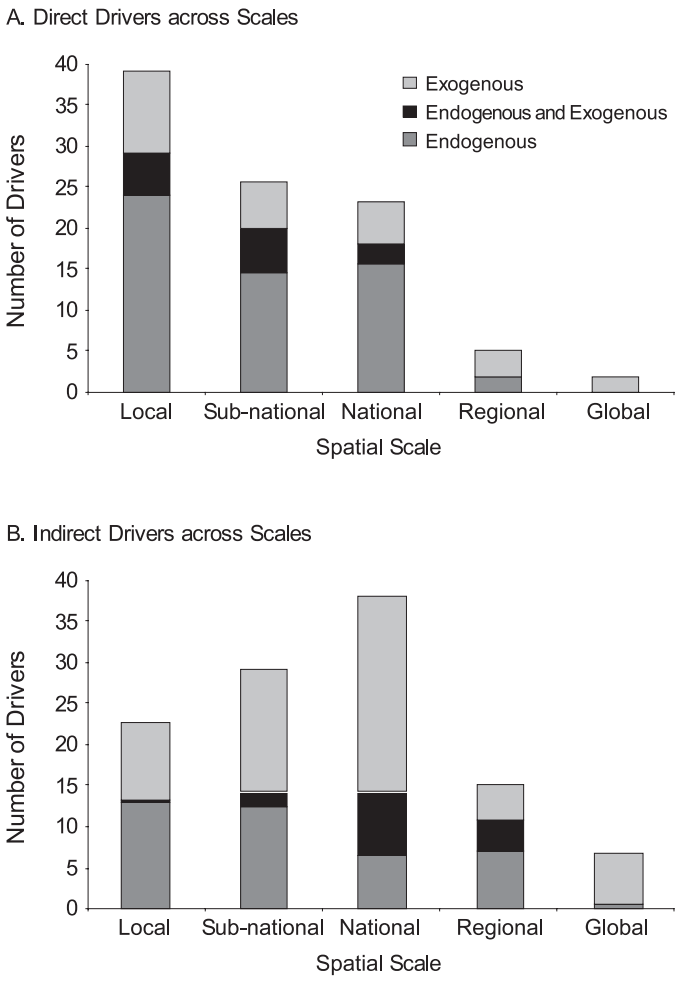

Figure 7.3. Direct and Indirect Drivers across Scales and Their Classifications as Exogenous or Endogenous

tween these two different scale features of drivers in their assessments, it was possible to make this distinction retrospectively in interviews with the assessment teams, especially during the knowledge markets (KM-1, KM-2). The distinction is helpful when assessing the controllability of drivers: a decision-maker often has more ability to control drivers that operate or change at the temporal and spatial scale at which the decision-maker is situated.

For driver speed, the following categorization was used: fast (F), medium (M), slow (S), and very slow (VS). A few drivers were classified in intermediate categories of medium-fast and medium-slow. The classification of driver speeds was determined through interviews with assessment teams and was based on the characteristic time scale of a driver's effects (that is, how long it takes for the driver to have a significant effect). The results are presented in Table 7.9.

Within the overall set of drivers in the sub-global assessments, 103 were categorized according to the spatial and temporal scales at which they operate. To analyze the relationship between spatial scale and speed, some aggregation was necessary. Drivers in the medium-slow and medium-fast categories were considered to be medium. Very slow drivers were considered to be slow. This left only three speed categories: fast, medium, and slow. When a driver was indicated as covering more than one spatial scale, it was split among those spatial scales. For example, if a driver was indicated as covering spatial scales ranging from local to national, it counted as one third for the local scale, one third for the sub-national, and one third for the national.

Table 7.9. Classification of Drivers by Temporal Scale. This classification of driver "speeds" was based on the characteristic time scale of a driver's effects, that is, how long it takes for a driver to have a significant effect.

	Fast	Medium	Slow	Very Slow
Local scale	< 1 year	1–5 years	> 5 years	
Sub-national to global scales	< 2 years	2–10 years	> 10 years	> 20 years

The five spatial scale categories (local, sub-national, national, regional, global) were aggregated into three categories: local and sub-national, national, and regional and global. Since the sampling on the spatial scales was biased due to the spatial scales of the sub-global assessments themselves, we normalized the number of drivers for each spatial scale. The final result is presented in Figure 7.4, resembling a similar figure in the MA conceptual framework (MA 2003, Figure 5.2), which presented the relationship between spatial and temporal scales conceptually.

It is often hypothesized that small scale processes are fast. For a large number of drivers identified in the sub-global assessments, the hypothesis holds that the coarser the spatial scale, the slower the process of change. However, a significant number of exceptions were observed. For example, the São Paulo assessment mentions governance and legislation as a local, but slow driver; similarly Downstream Mekong

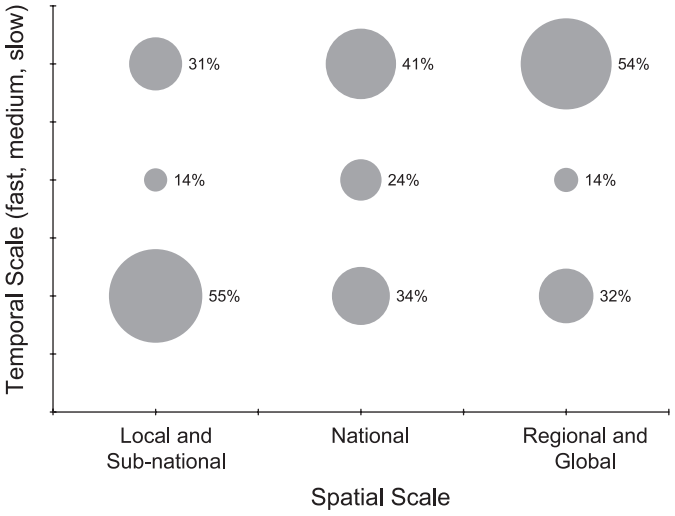

Figure 7.4. Relationship between Spatial and Temporal Scale of all Drivers Considered in the Sub-global Assessments. The size of the circles represents the proportion of drivers at a certain spatial scale which had a certain speed (e.g., of all the drivers mentioned on local and sub-national scales, 55% were fast). The general pattern is that fine spatial scale (local and sub-national) processes tend to be fast, while coarse spatial scale (regional and global) processes tend to be slow. Notable exceptions are discussed more thoroughly in the text (see also Figure 5.2 in the MA conceptual framework).

considers soil degradation a slow local biophysical driver. On the other hand, in San Pedro de Atacama, the rapid change of technology in the mining sector taking place worldwide is an important driver. This character of technology (that is, fast change on the global or at least national scale) also holds for the Argentine Pampas.

Table 7.10 summarizes the 103 drivers according to speed and directness in relation to the MA driver categories. Biophysical drivers have been further subdivided into land use change, species introductions, pollution, climate change, and others.

Among indirect drivers, demographic, sociopolitical, and cultural and religious drivers are generally slow, while science and technology is fast. Among direct drivers, it appears that biophysical drivers split into two groups: fast drivers related to pollution, land use change, and ''others''; slow drivers related to climate and species introductions. Economic drivers do not have a well-defined behavior according to this classification.

7.4 Integrating Drivers

7.4.1 Assessment Process

For the sub-global assessments, analyzing the interactions among the multitude of drivers was not surprisingly more difficult than the assessment of individual drivers. This was often due to a lack of quantitative data or to the availability of these data only late in the assessment processes. Extensive statistical work to assess the interplay of drivers was not feasible for most assessments. The SAfMA Zambezi Basin component assessment was unique in that it was able to draw on previous work to capture the interactions among drivers (SAfMA Zambezi).

Most of the assessments used qualitative methods to assess interactions among drivers. These methods differed in the degree to which stakeholders and users were involved, and whether literature and theoretical knowledge was used. In general, it appears that pragmatic considerations dominated when choosing the assessment methods. Factors influencing the choice of methods were:

- the degree to which contacts with potential users of the assessment had been established before the launch of the assessment. Existing contacts made it easier to involve users, and thus led to a stronger user-driven assessment; and
- the disciplinary composition of assessment team members as well as their experience with the assessment area. The Zambezi Basin assessment within SAfMA illustrates the benefits of longer work within the region, as various tools such as models already existed when the local assessment began (KM2).

The following discussion of interactions among drivers should be read in the context of the limitations in assessment methods and the often preliminary character of the information found within the individual sub-global assessments.

Table 7.10. Relationship between Speed and Directness of Drivers. The main categories of drivers were classified as being fast or slow, and direct or indirect. There was no general pattern for economic drivers (that is, they were as often slow as fast).

	Fast	Slow
Direct	biophysical—pollution biophysical—land use change biophysical—others	biophysical—climate biophysical—species introductions
Indirect	science and technology	demographic sociopolitical cultural and religious

7.4.2 Cross-scale Impacts of Drivers

Identifying drivers at the global scale does not provide a complete picture of their effects at national and sub-global scales. For example, changes in trade flows brought about by increased economic openness trickle down to the local level and can alter the demand for ecosystem services. In Viet Nam, export demand for shrimp, triggered by integration into the world market, resulted in the conversion of mangroves for shrimp farming. In addition to the positive service of increased shrimp production, there were negative environmental effects such as the intrusion of brackish water into freshwater ecosystems, the destruction of coastal ecosystems, and coastal erosion (Downstream Mekong).

In the sub-global assessments, three general modes by which global and national drivers ''trickle down'' to the local scale were observed. Trade drivers can be used to illustrate these modes. In the first mode, global and national scale drivers jointly influence ecosystem change at the local scale. (See Figure 7.5.) For example, in the Laguna Lake Basin in the Philippines, land conversion from agriculture to industrial zones is driven by demand for and trade of products such as cars and semiconductors at *both* the global and national scales. To produce these products, transnational companies are enticed by the national government to invest in industrial parks within the basin. These industrial parks are built on rich alluvial plains that were formerly prime agricultural areas. They have major impacts on the lake ecosystem by reducing water quality through pollution, and reducing the lake's bioproductivity (Laguna Lake Basin).

In the second mode, global (or sometimes regional) drivers directly influence change in ecosystems at the local scale, with little mediation from national or regional scale drivers. This is illustrated in the case of the Kristianstad wetlands, where increased precipitation, probably due to large scale shifts in weather patterns throughout Europe (Werner et al. 2000) has induced increased flooding with impacts on local ecosystems (Sweden KW). Another example is in India, where global demand for areca nut has caused a shift in land use from paddy fields to areca plantations (India Local).

In the third mode, local ecosystem change is largely driven by national drivers independently of global or regional drivers. For example, in Sinai, demand for agricul-

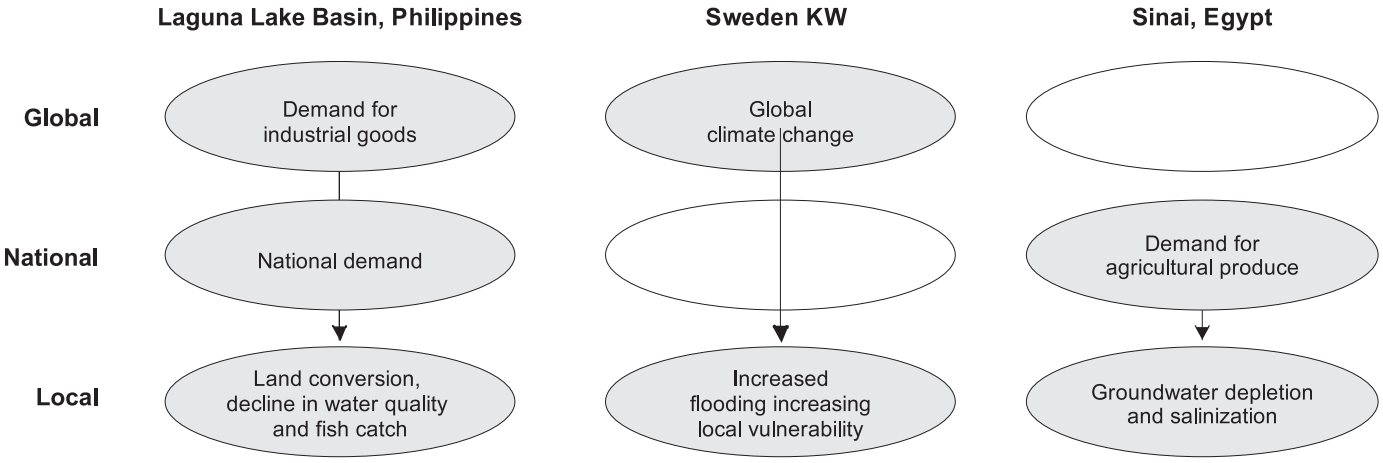

Figure 7.5. Three Modes by which Global and National Drivers "Trickle-down" to the Local Scale

tural products at the national scale caused intensification of agricultural cultivation that led to groundwater depletion, increased soil salinity, and eventual replacement of native species with introduced species.

From the preceding discussion, three related lessons emerge:

- Global drivers can reinforce national drivers to enhance their effect on ecosystem change at the local scale. In this case, global-scale drivers might actually be partially endogenous for national decision-makers.
- Global drivers can cause changes in ecosystems directly at the local scale, without interacting with national or regional drivers. In this case, controllability might be difficult.
- National scale drivers can influence ecosystem change at the local scale apart from global drivers. Here, controllability is purely at the national scale.

7.4.3 Interactions among Drivers and their Impacts

No individual driver could be identified as key across all the sub-global assessments, nor did any single driver appear to be of equal relevance across the assessments. It appears that drivers act in very distinct ways in different places, and though a similar driver (for example land use change) might be identified throughout many assessments, the actual processes by which this driver operates can be very different (see Tropical Forest Margins example discussed below). The drivers in each location do interact, and these interactions are key elements of the social-ecological system in that location. The uniqueness of these interactions is a major reason for carrying out independent sub-global assessments.

Despite the uniqueness of driver interactions, certain patterns of interactions are evident. For example, 12 out of the 20 assessments analyzed identified drivers concerning smallholder agriculture (Argentine Pampas, Altai-Sayan, San Pedro de Atacama, Tropical Forest Margins, India Local, PNG, Portugal, SAfMA, Northern Range, Downstream Mekong, Eastern Himalayas, Sinai). Although differing in detail, there is a degree of similarity in the processes by which smallholder farming has an impact on ecosystems. It should be noted, however, that there are differences even within individual assessments. For example, the different SAfMA local assessments depict variations in the drivers of change in smallholder agriculture. Thus the idea of interaction patterns should only be seen as a rough aggregation scheme to systematize the complexity of the socioecological systems assessed. Besides the processes behind changes affecting smallholder agriculture, interactions of drivers in the following areas were also considered:

- commercial resource exploitation (in 7 sub-global assessments);
- economic development strategies (in 8 assessments);
- processes of urban change (in 5 assessments);
- tourism (in 8 assessments); and
- natural extreme events (in 6 assessments).

7.4.3.1 Smallholder Agriculture

In smallholder agriculture, a number of indirect drivers induce changes in agricultural production. (See Figure 7.6.) The following three indirect drivers are mentioned in various sub-global assessments:

- *Fluctuating market prices and changes in market access*. In Altai-Sayan, the increase in market prices for cashmere resulted in the intensification of herding. Herders and their livestock moved closer to towns to have better market access. This increased the pressure on grasslands in these areas with degradation of soils and vegetation, reducing the provisioning of fodder. In the Northern Range of Trinidad, the liberalization of trade and the resulting competition forced down local produce prices, which made local production of market crops uneconomical. In Portugal, the decrease of agricultural producer prices also led to a decrease in productivity; the people's efforts to balance the potential income losses brought about three types of change: intensification in ecologically more productive regions, extensification on less productive land, and abandonment in cases where more attractive income opportunities were available. Lack of knowledge was also mentioned in Western China and Altai-Sayan as contributing to increased pressure on ecosystems by smallholder agriculture.
- *Population pressure creating increased need for agricultural produce from smallholdings*. The Downstream Mekong assess-

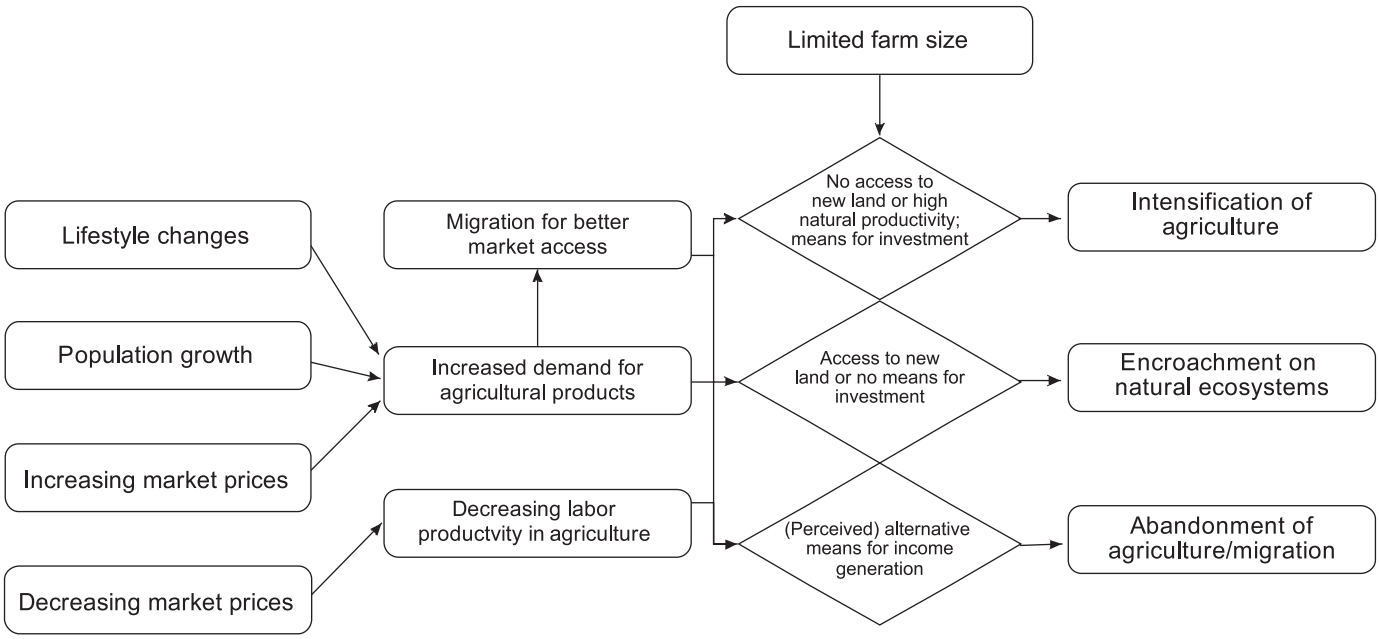
Limited farm size
Lifestyle changes
Population growth
Increasing market prices
Decreasing market prices
Migration for better market access
Increased demand for agricultural products
Decreasing labor productvity in agriculture
No access to new land or high natural productivity; means for investment
Access to new land or no means for investment
(Perceived) alternative means for income generation
Intensification of agriculture
Encroachment on natural ecosystems
Abandonment of agriculture/migration

Figure 7.6. Interactions among Drivers, and Their Impacts, in Smallholder Agriculture

ment states that the pressure depends ''on the state's socioeconomic development policies, the local human awareness and the actual conditions of the locality'' (Downstream Mekong, p. 36). Eastern Himalayas refers to population growth as a major driver.

- *Growing aspirations and changes in lifestyle.* Both Downstream Mekong and San Pedro de Atacama called these important drivers, and indirect evidence of their role can be found in other sub-global assessments. The impact is via increasing demand for ecosystem services. ''From late 80s to present, local livelihoods have basically changed, shifting from self-supporting to market-oriented, the latter being ruled by free market economic principles. More profits gained in the open economy have led to increases in individual incomes, leading to higher demands for ecosystem services, especially those related to land, water and forest products.'' (Downstream Mekong, p. 38).

These main indirect drivers are mediated by two other major indirect drivers: the size of holdings often related to land tenure and outmigration to seek improved living conditions. Depending on the actual pressure and the availability of land, three major outcomes can be observed:

- *Intensification.* With respect to land tenure, evidence from the general literature (Kates and Haarman, 1992) and also from the sub-global assessments indicates that problems relating to intensification arise if landholdings are too small (India Local, Portugal). This may happen for different reasons, such as division of land among siblings or land reform acts (India Local). The limitations of land induce an intensification of production beyond the limits of ecological capacity of the land. Within the sub-global assessments, intensification is reflected in increased application of fertilizers and pesticides (India Local, Eastern Himalayas, Sinai) or increased grazing (Altai-Sayan, Argentine Pampas). The sub-global assessments also reveal that intensification occurs in the whole range of farming strategies, from commercial (Portugal) to subsistence (SAfMA).
- *Encroachment on natural ecosystems, in particular forests.* Increasing needs for agricultural production, either for subsistence or for income, lead to continued clearing of forests (Eastern Himalayas, PNG). For example, in the Darjeeling Hills of the Eastern Himalayas, people now have to collect softwood rather than the preferred hardwood in the public forests either for their own fuelwood needs or for selling in the markets, as hardwood has disappeared due to unsustainable cutting in the past. To satisfy the demand for wood, an even larger area has to be harvested, because of the lower energy density of softwood.

  According to the Tropical Forest Margins assessment, slash-and-burn agriculture is not the only, or even the key, driver of deforestation. Other important drivers include commercial wood extraction, (permanent) cultivation, livestock development, and the extension of overland transport infrastructure. Deforestation driven by swidden agriculture is more widespread in the upland and foothill zones of Southeast Asia than in other tropical regions of the world. Road construction by the state followed by colonizing migrant settlers, who initially practice slash-and-burn agriculture, is most frequent in lowland areas of Latin America, and especially in the Amazon Basin. In addition, pasture creation for cattle ranching is a cause of deforestation that occurs almost exclusively in these regions. In Africa, the spontaneous expansion of smallholder agriculture and fuelwood extraction for domestic use are important causes of deforestation.
- *Abandonment.* In less productive areas of Portugal, people are leaving the agriculture sector for more attractive

jobs (for example, within the tourism sector), leading to abandonment and afforestation of formerly agricultural lands. In more productive areas, intensification of agriculture is taking place (for example, with increased use of inorganic fertilizers and pesticides which reduce ground water quality).

Interestingly, none of the sub-global assessments considered the effects of large-scale agriculture in detail.

7.4.3.2 Extraction of Natural Resources

This section focuses on the direct, for-profit or subsistence-oriented extraction of wood from forests or of fish. Note that impacts on forests can also be induced by other processes (for example, extension of smallholder agriculture on new land or fires, discussed below). With regard to the direct extraction of wood or fish from natural ecosystems, the following four direct drivers appear in various assessments:

- *Commercial logging.* The selective logging activities of Malaysian companies in Papua New Guinea have extended towards the western border with Indonesia (KM2–PNG). This is not seen as a major source of degradation by local people, as it is perceived as something which has been going on in the past anyway. There is an issue, however, relating to who receives the benefits. In India, the current system of offering time-bound leases for forest exploitation has led to overexploitation (India Local).
- *Fuelwood extraction.* Local people, especially women, have to spend more time and effort to gather increasingly diminishing supplies of fuelwood (India Local). The overexploitation of high-yielding fuelwood (hardwood species) is one of the main factors that has contributed to destruction of forest ecosystems (Eastern Himalayas). One backload of Buk (*Quercus lamellosa*) wood provides two hours burn time. The same quantity of other species like Kharaney (*Symplocus theifolia*) gives only 30 minutes burn time and therefore needs to be harvested in higher quantities.
- *Unsustainable extraction of other resources.* In São Paulo, for example, this includes palm heart, bromeliads, orchids, and wild animals; in the Eastern Himalayas, it includes mosses and medicinal and aromatic plants; in Papua New Guinea: hunting of wild animals and birds and gathering of wild plants and fruits. Another aspect is the illicit grazing of cattle and lopping trees for fodder (Eastern Himalayas).
- *Fishing.* Overfishing by outside trawlers is an important issue in Bada village, India, where local people interviewed during the assessment reported that fish resources were declining. Fishing during the breeding season has resulted in the loss of local fish availability. Fishery resources are now neither abundant nor diverse. The destructive fishing methods such as the use of dynamite and poisons have led to the depletion of fish, which are now estimated to be around 25% of the levels experienced by older people in the village (India Local). In Papua New Guinea, dynamite fishing is cited as a problem. From the literature it is known that dynamite fishing can have serious impacts on coral reefs, and might even induce a phase shift to soft-coral colonization as hard corals have difficulties recovering on the rubble zones caused by dynamite fishing (Fox et al. 2003). Yet, for the time being, such phase shifts have not been observed in the coastal areas of Papua New Guinea (PNG). In the coastal areas of British Columbia (Canada) fishing has either caused declines of fish populations or exacerbated the effects of habitat degradation, with competitive pressure exerted by foreign and domestic fleets and—within the domestic fleet—commercial, recreational, and aboriginal components (Coastal BC).

Two feedback loops (see Figure 7.7) at different scales were only briefly mentioned in sub-global assessments, but can also be found in the literature (Geist and Lambin 2002; Cassel-Gintz and Petschel-Held 2000).

- *Local loop.* The indirect driver of increasing demand for fuelwood creates a local loop through the direct driver of wood harvesting. With the overuse of traditional collection grounds, people shift to harvesting wood from formerly untouched forests, or they harvest types of wood they have not used before. This causes local encroachment on forests that can be expected to continue, and thus might lead to self-reinforcing encroachment.
- *Global loop.* The overexploitation of forests and fisheries creates a global loop, where commercial companies shift from overexploited areas to new areas that have similar patters of resource extraction (the direct driver) to meet global market demand (the indirect driver).

7.4.3.3 Development Strategies and Plans

Economic development programs implemented by national governments, in some cases with assistance from international development agencies, can help poor rural people improve their well-being, but can also have unintended negative effects on ecosystems. The sub-global assessments contain a number of examples. The generalized structure of the underlying mechanisms is depicted in Figure 7.8.

- *Macroeconomic policy reform.* The introduction of market-oriented macroeconomic policies is often promoted by external actors like the World Bank or the International Monetary Fund. In many countries in southern Africa, these policies included the withdrawal of government subsidies, facilitation of privatization, and removal of pan-territorial pricing (SAfMA). The performance of aggregate agricultural production under structural adjustment was disappointing, as production growth did not keep pace with population growth between 1990 and 1997. At the livelihoods level, market liberalization, and particularly the way in which it was applied, has removed some of the institutional support that provided a safety net for the food insecure, and smallholder farmers have become more vulnerable to livelihood shocks, particularly in times of market failure (Scholes and Biggs 2004).
- *Population resettlement.* Sometimes governments seek to relieve population pressure—and thus to a certain extent also the pressure on the environment—by promoting major development efforts in more remote regions. The Egyptian government, for example, seeks to develop the

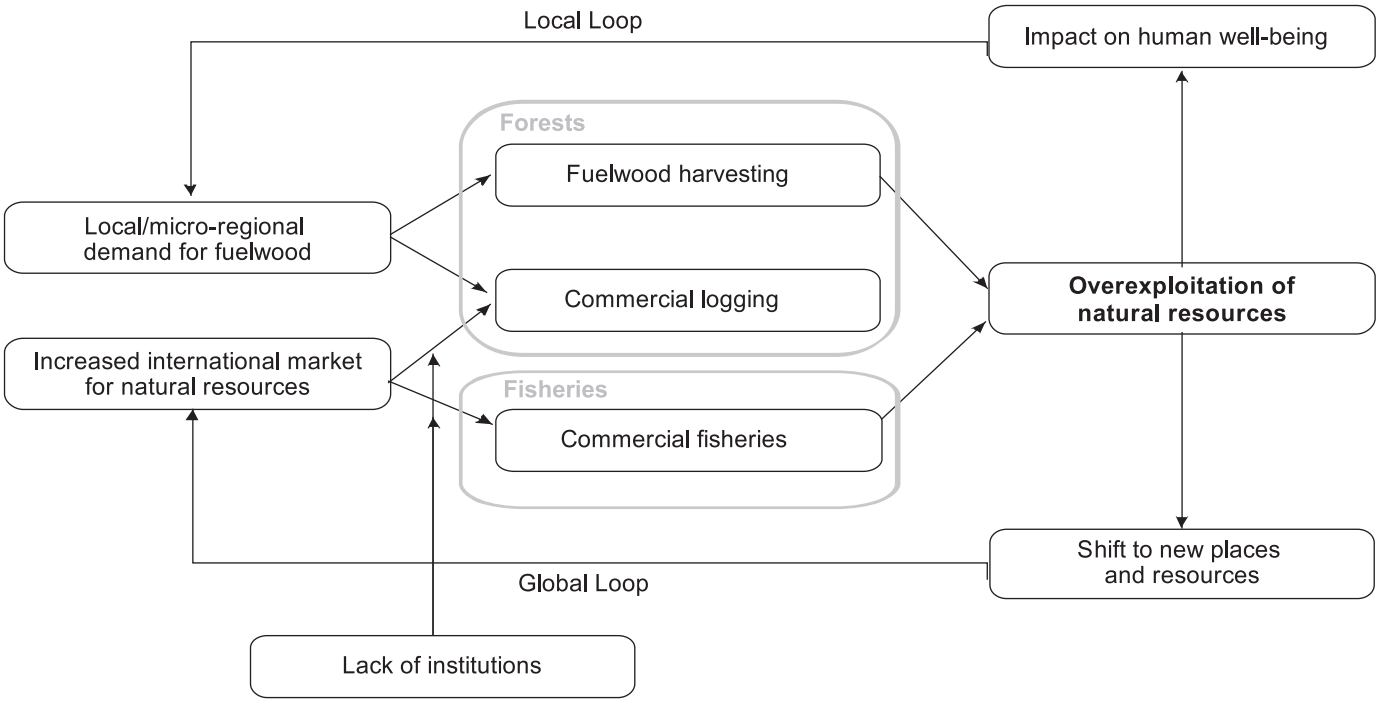

Figure 7.7. Interactions among Drivers, and Their Impacts, in the Extraction of Natural Resources

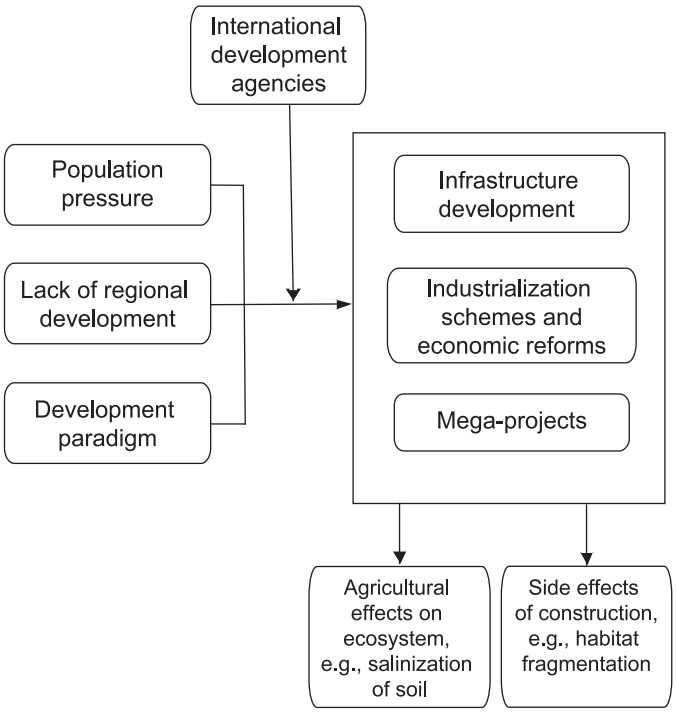

Figure 7.8. Interactions among Drivers, and Their Impacts, Arising from Economic Development Strategies

northern part of the Sinai peninsula for a total of 6 million people in order to reduce the high population density in the Nile valley. This will include the development of heavy industries, export processing zones, and agricultural projects with potentially significant impact on ecosystems such as pollution and salinization of soils (Q2–Sinai).

- *Infrastructure development.* Infrastructure development in remote areas or in areas close to cities where it might induce urban sprawl or growth is often a development strategy. In the metropolitan area of São Paulo and Santos, for example, infrastructure investments are targeted at providing opportunities for the secondary sector. The resulting urban growth fragments habitat or causes increases in pollution levels (see below). In more remote areas like the Amazon Basin, infrastructure development triggers streams of incoming settlers, who in turn practice slash-and-burn agriculture leading to decreased soil fertility in the long run (Tropical Forest Margins). In the Darjeeling region in the Eastern Himalayas a total of 85 dams are proposed mainly for electricity production, which will have impacts on ecosystems through the fragmentation of habitats of flora and fauna (Eastern Himalayas).

These drivers raise a major evaluation problem as it is often not easy to compare their benefits for human well-being, in terms of new income opportunities or improved infrastructure, with the negative consequences on human well-being via ecosystem change. For more details on the lack of evaluation tools for dealing with these types of trade-offs, see also MA *Current State and Trends.*

7.4.3.4 Urban Processes

Sometime in the first decade of the twenty-first century, the threshold of 50% of the global population living in urban areas will be crossed (MA *Scenarios,* Chapter 7). This figure differs widely between industrial and developing countries, with some 80% of the population of industrial countries in urban areas, and 40% in developing countries. For assessing ecosystem changes, the effects of conversion of land to

urban use needs to be distinguished from the effects of change within existing urban areas. Whereas the expansion of urban areas basically represents a form of land use change, existing urban areas cause pollution, waste generation, and resource use with effects that can be felt far from the urban area itself. Both aspects of urban change are addressed within the São Paulo sub-global assessment (São Paulo). The process of urban growth and/or sprawl is addressed in a few other assessments (Sweden SU, Sweden KW, Caribbean Sea, Northern Range). The impacts of urban lifestyles are discussed in Coastal BC. These two types of urban process (that is, expansion in urban areas and growing urban populations) have somewhat different impacts on ecosystems, as indicated in Figure 7.9.

The case of the huge metropolitan region of São Paulo illustrates the dimensions of material flows induced by a population of around 18 million people. The metropolitan area produces 20,000 tons per day of domestic waste and 60,000 tons per month of civil engineering rubble in the municipal district. The resulting problems are amplified by the dual character of the area, comprising a *formal city* that receives most of the public investments and an *informal city* that is growing exponentially (and illegally), exacerbating social and environmental dissimilarities. These problems are exacerbated by the prevailing growth of the metropolitan area, both in terms of area and to a lesser extent in terms of population. Between 1980 and 1991, the population grew by 22.9%. An additional 15.7% growth occurred between 1991 and 2000. The large population in the Metropolitan Region of São Paulo and the related problems of overpopulation and housing tend to drive people toward the surrounding zones, consuming important natural resources (São Paulo).

In contrast, urban areas in industrial countries are dominated by urban sprawl. Both within the urban area of Stockholm and in the Kristianstad wetlands, urban sprawl is a major driver of ecosystem change (Sweden SU, Sweden KW). In the Kristianstad wetlands, extension of sealed urban land leads to increased flooding. In Stockholm, ecologically valuable land is converted, thus destroying corridors for species migration and leading to a loss in genetic diversity.

7.4.3.5 Tourism

For the sub-global assessments that found tourism a driver of ecosystem change, the effects were mainly due to the construction of buildings and other infrastructure, mainly on the coastal strips of islands (Caribbean Sea) or in coastal mainland areas (Portugal, Sinai). Figure 7.10 illustrates how tourism affects ecosystems. The sub-global assessments provide a number of examples of how tourism might in the future undermine its own basis, that is, damaging those amenities that originally drew tourists.

Tourism has been increasing steadily in the coastal areas of Portugal—in the Algarve and the coast of Lisbon and now in the coast of Alentejo—where it damages estuaries by excessive water consumption and/or pollution. The pressure of tourism comes to an extent from international tourism markets, but is mostly domestic, through internal demand for holiday houses and the economic interests of the construction sector (Portugal).

The tourism industry is the major source of investment in the Sinai. Its negative effects on ecosystems and their services include reduced biodiversity and damage to coral reefs in the Red Sea off the coast of the Sinai peninsula in Egypt. The coral damage eventually prompted government intervention to enforce protection measures and rehabilitate coral reefs. Massive amounts of solid waste and wastewater from hotels and other new establishments are newly emerging problems in Sinai (Sinai, KM2–Sinai).

In the San Pedro Basin in Chile, tourism is seen as competing with mining for limited water resources. Mining makes tourism unattractive, yet the assessment has evaluated tourism as a major cause of land use change (San Pedro de Atacama).

In some cases, massive investment in tourism (for hotels, roads, marinas) effectively creates an economic monoculture, which is the case in almost all the islands of the Caribbean (reaching 99% of GDP in the Bahamas). The main exception is Trinidad, which receives about 70% of its GDP from the petroleum sector. Investments in the tourism sector (in many cases foreign) often lead to land use changes on flat coastal land or land that has been reclaimed from the sea. This impacts coral reefs, seagrass, and mangrove swamps (Caribbean Sea). Cruise ships, which bring in a major portion of the tourists in the region, often dispose their used water into the sea, which leads to increased nutrient input and thus affects marine ecosystems.

In southern Africa, nature-based tourism is one of the fastest-growing sectors. According to the southern African

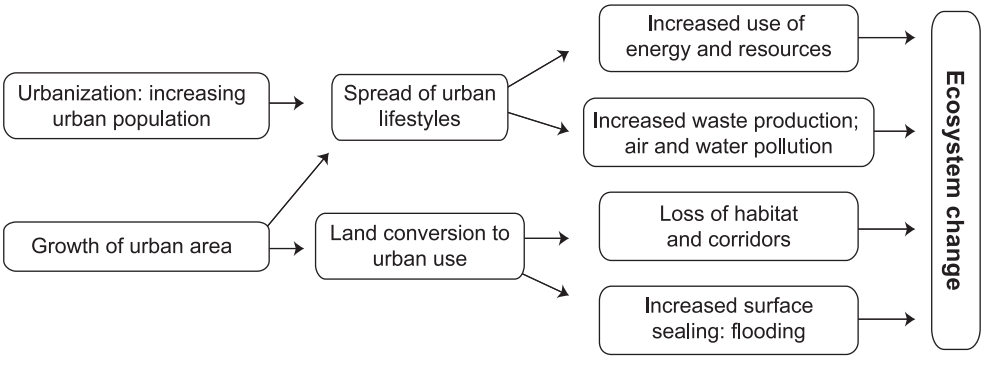
Urbanization: increasing urban population
Spread of urban lifestyles
Increased use of energy and resources
Increased waste production; air and water pollution
Growth of urban area
Land conversion to urban use
Loss of habitat and corridors
Increased surface sealing: flooding
Ecosystem change

Figure 7.9. Interactions among Drivers, and Their Impacts, from the Growth and Expansion of Urban Areas

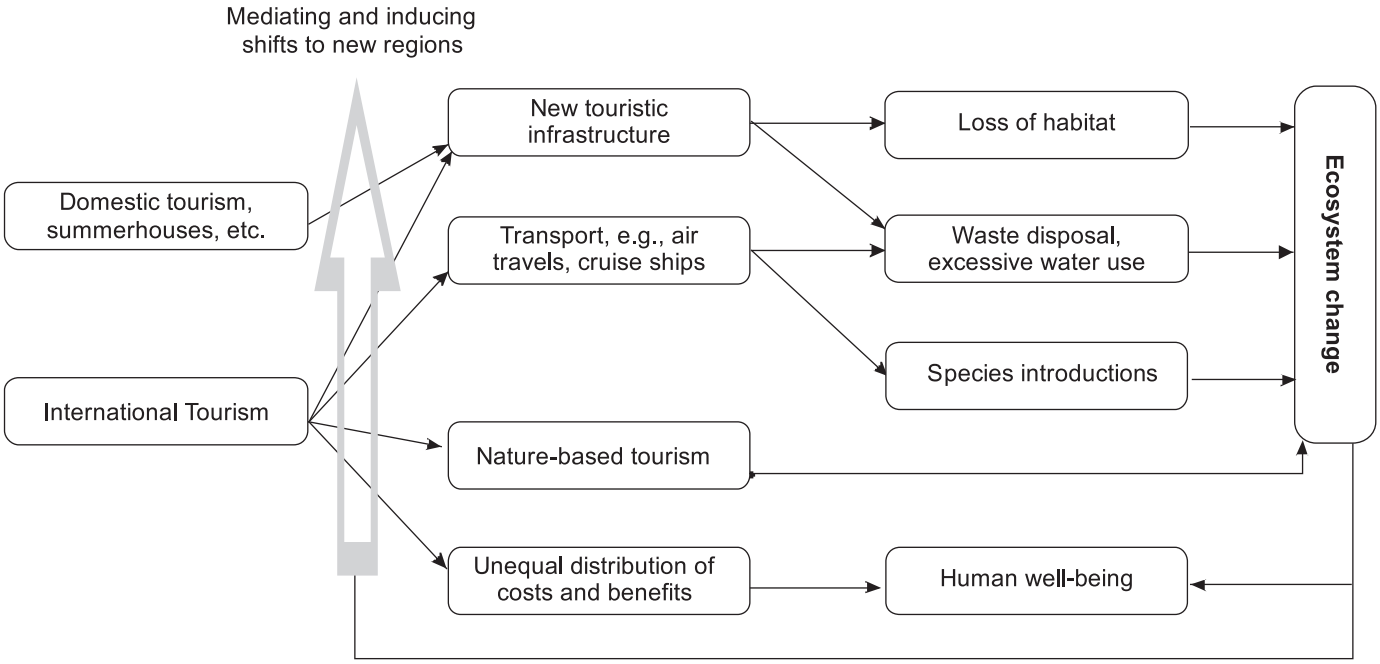

Figure 7.10. Interactions among Drivers, and Their Impacts, Related to Tourism. Note that there is a strong option for mediating the negative consequences by development of sound tourism concepts. Furthermore, a feedback loop exists due to ecosystem change that reduces landscape amenity, thus inducing a potential shift of tourism to new regions.

regional assessment (Scholes and Biggs 2004), the attraction of the region for nature tourism is mainly related to some elements of structural biodiversity, particularly the ''big five'' of lion, elephant, rhinoceros, buffalo, and leopard. A major problem related to nature tourism in the region is the distribution of costs and benefits. According to some studies in the region, the fraction of the sector turnover that accrues to local people can be as low as a few percent, whereas the negative impacts at the local level are considerable due to the inappropriate treatment of sewage and other wastes and from ''visual pollution'' due to badly designed and poorly sited developments (Scholes and Biggs 2004).

7.4.3.6 Natural Disasters and Extreme Events

Natural disasters have always been important drivers of ecosystem change. Until the second half of the twentieth century, global climate has changed independently of human activities (IPCC 2001). Fire has always been an important element of the successional cycles of ecosystems, and tectonic activities like volcanic eruptions, earthquakes, and tsunamis have had major consequences for ecosystems and human well-being. Yet more recently, there is increasing evidence that human activities are having an effect on the frequency and intensity of extreme events. The sub-global assessments add evidence with respect to changes in fire regimes and to a lesser extent also to climate. Figure 7.11 sketches the general structure of these effects.

The Altai-Sayan and Portugal assessments report that fire is a major driver of change in their assessment areas. In Altai-Sayan, differences in the fire regime across the region are due to natural climatic conditions; there is as yet no indication that climate change has had an impact on changes in the fire regime or on shifts of treelines in the region

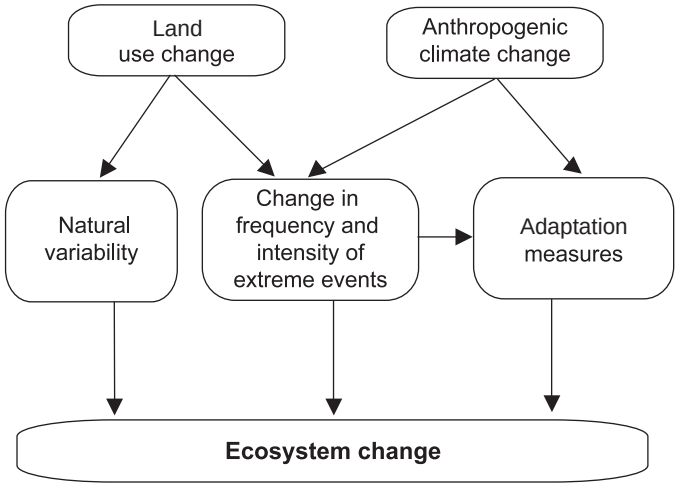

Figure 7.11. Interactions among Drivers, and Their Impacts, Related to Extreme Events. It has become increasingly evident that these changes mostly relate to increases in frequencies or intensities, or both.

(Altai-Sayan). In Portugal, the fire regime has become more pronounced over time. For example, in 2003, 5% of the area of Portugal burned, which was the largest area affected by fire in the country's recent history (Portugal).

In Kristianstad, normal annual flooding is a natural dynamic of the ecosystem, which had always had a high buffering capacity to regulate flooding in the watershed, limiting the damages to humans. Yet the extreme annual flooding events in the recent past (caused by very high precipitation) hint at a possible reduction of this buffering capacity. This loss is possibly due to direct drivers such as land

use change, watercourse simplification, and the building of drainage ditches. Beyond the direct effects of the observed extreme floods, biodiversity loss may be an additional consequence (Sweden KW).

Tropical cyclones are seen as a major driver of ecosystem change in the Caribbean Sea. During the 1990s, the frequency of tropical cyclones increased compared to earlier decades. General public opinion interprets this as an effect of climate change, but analysis of the time series for several decades shows that there has as yet only been a small increase in recent occurrences. It remains unclear whether the increase is within the range of natural climate variability, or whether climate change is responsible for the change. The impacts of tropical cyclones on coastal areas are exacerbated by heavy economic investments in coastal areas and also by some recent coral diseases, among others due to the import of bacteria by Saharan dust (Caribbean Sea).

In Papua New Guinea, periodic droughts, as part of climatic variability, have always been a problem. However, there is evidence that climate change is making these droughts more frequent. Also in Papua New Guinea, volcanic activity and extreme weather events have a significant effect at the local scale. Coastal ecosystems are also vulnerable to damage by tectonic activities and tsunamis (PNG).

7.4.4 Patterns of Interaction

Given the interactions and impacts described, it is possible to evaluate these together to check for patterns across all the sub-global assessments. Table 7.11 provides an overview of the different sub-global assessments and the processes of driver interactions.

In only two assessments, Western China and Sweden SU, ecosystem change appears to be driven by a single major process. Although in both cases, the process indicated is indeed dominant, this does not necessarily imply that other processes are not taking place or that these might come to play a more important role in the future. In Sweden SU, for example, processes of learning and institutional change are emerging, which is an indicator of hope for better future planning and land management strategies (Jakob Lundberg, personal communication).

The other assessments show that several processes of ecosystem change are interwoven. In many cases the interactions between these processes do not just add up, but can trigger, reinforce, or sometimes also constrain one another. Table 7.12 shows the three major modes of interaction; it is based on results from the various sub-global assessments as well as from other sources:

- *Triggering*. Deforestation provides an example of how one process of ecosystem change can trigger others. Particularly in Latin America, the commercial exploitation of forests clears space for settlers to move into the forests and cause further ecosystem change through cultivation (Tropical Forest Margins). Impoverishment and induced migration within smallholder systems can themselves trigger processes of urbanization (rural–urban migration as in São Paulo) or economic development strategies to alleviate underdevelopment (Eastern Himalayas). It can also aggravate the effects of natural disasters due to a lack of adaptive capacity (for example, the decreased resilience of coastal ecosystems to tropical cyclone impacts in the Caribbean Sea).
- *Reinforcing*. Processes can also enhance the effects or intensities of others. Resettlement projects designed to release the pressures on the natural and social environment in the densely populated regions of coastal Southeast Asia has intensified land use change in the rural inland areas due to swidden agriculture in the forest margins (Tropical Forest Margins).
- *Constraining*. In some cases, processes can be constrained by others. Natural disasters and resource exploitation can easily reduce the attractiveness of a region for tourism. More generally, however, ecosystem change reduces the recreational value of ecosystems (for example, Portugal).

The complex interactions among drivers can make efficient responses to ecosystem change difficult. Influencing individual drivers is seldom sufficient, as any given driver is almost always embedded in a system of interactions like those assessed in this section. Before examining possible responses, however, it is necessary to look into the implications of potentially nonlinear interactions between drivers.

7.5 Drivers and Thresholds

Changes in drivers are often nonlinear; thus an abrupt or extreme change in a driver is not always possible to anticipate, and seemingly small incremental changes can have massive effects. Problems may arise when a driver or an interaction changes in such a way that a critical threshold is exceeded, beyond which ecosystem service delivery or associated human well-being is compromised. How drivers change and interact can determine if and when critical system thresholds are passed.

Unfortunately, there are only hints found in the sub-global assessments that the interactions between drivers operating or changing at different temporal and spatial scales can play a role in pushing social-ecological systems past critical thresholds. In some cases, the interaction is between climate, which tends to change slowly, and changes in land use, policies, or markets, which change more quickly. In the Argentine Pampas assessment, the interaction between climatic conditions that were more favorable for farming, and the aggressive intervention of commercial firms between 1970 and 2000, has driven a westward expansion of the annual-crop boundary onto rangelands and grasslands. This interaction has boosted agricultural productivity and rural incomes in the short-term, but has had a negative effect on soil stability in the long-term. However, the accumulated degradation of soils has triggered a feedback mechanism in some areas that has prevented further expansion of annual crops (Argentine Pampas).

In British Columbia, climate events—notably the El Niño–La Niña cycle—are cited as a major driver of ecosystem change, along with other less predictable influences, possibly linked to global warming. Against this background, the main drivers of environmental change are harvest pres-

Table 7.11. Major Processes of Driver Interaction across the Sub-global Assessments

Sub-global Assessment	Smallholder Agriculture	Resource Extraction	Economic Development	Urban Growth	Tourism	Natural Disasters	Number of processes
Altai-Sayan	■					■	2
ASB	■	■					2
Coastal BC		■					1
Caribbean Sea					■	■	2
Darjeeling Valley	■		■				2
India Western Ghats	■	■	■				3
Sweden KW				■	■	■	3
Downstream Mekong	■	■	■				3
Papua New Guinea	■	■				■	3
Portugal	■				■		2
SAfMA Gariep	■		■		■		3
SAfMA Regional	■		■		■	■	4
Sinai	■		■	■	■		4
San Pedro de Atacama	■				■		2
Sweden SU				■			1
Laguna Lake Basin		■	■				2
Northern Range	■			■	■		3
Western China		■	■	■		■	4
Number of assessments		12	7	8	5	8	6

Table 7.12. Modes of Interaction among Processes. Key: T = Trigger; R = Reinforce; C = Constrain.

Interactions: ↓ acts on →	Smallholder Agriculture	Resource Extraction	Economic Development	Urban Change	Tourism	Natural Disasters
Smallholder agriculture			T	T		R
Resource extraction	T				C	R
Economic development	T	T			T	
Urban change	R	T				
Natural disasters	T,R				C	

sure and introduced species. The timber sector has the most extensive effect on land ecosystems through conversion to roads and modification by logging. Logging has caused declines of the most sought-after timber populations. Thus in the case of British Columbia, a global driver (climate change) interacts with national, regional, and local drivers (Coastal BC).

Portugal reports a particular web of interactions between policy and biophysical drivers operating and changing at different scales. Economic growth in the 1960s and the integration of Portugal into the European Union in the 1980s and 1990s spurred growth in the industrial and services sectors. This has resulted in increased labor costs in agriculture (in the form of hired labor costs for agricultural companies or opportunity costs for farmers exploiting their farms directly). At the same time, entry into the EU Common Market and the reform of world trade agreements has led to lower agricultural prices, only partially compensated by subsidies. Hence, maintaining economic viability requires an increase in labor productivity, through either extensification or intensification. One outcome has been the conversion of some agricultural land to fast-growing forest plantations (eucalyptus or pines), which has contributed to increased fire frequency. Fire often leads to abandonment, both by itself and through increased soil erosion. The abandonment of agriculture facilitates the establishment of shrubs as land becomes increasingly degraded, affecting fauna and flora, and creating conditions for the development of frequent and severe fire cycles and loss of soil, and diminishing the system's capacity to recover. This invasion

of shrubs in the sub-cover after abandonment of agriculture activities is particularly well known in the holm oak *montado* (Portugal).

Many sub-global assessments have not specifically pinpointed the location of critical thresholds. These thresholds are not commonly identified until they are reached, simply because the information is lacking, or signs that they are being approached may be ignored or masked through technological or political mechanisms. Nevertheless, many ecosystems assessed by the sub-global assessments exhibit the characteristics that tend to result in such situations. Crises in social-ecological systems often occur at the intersection of large-scale processes and changing local variability, as local problems cascade up to higher levels (Gunderson et al. 2002). They also seem to emerge when people respond to drivers at one scale but ignore those occurring at others.

While crises may result from changes in drivers, crises can also trigger further change, as several sub-global assessments indicate, underscoring the importance of analyzing drivers within a broader systems perspective. (See Box 7.1.) Understanding where the critical thresholds lie is therefore essential to anticipating when a response is likely to be needed, which response options are likely to be available, and which response options are most likely to succeed. As noted in the Argentine Pampas assessment, climate is not completely controllable, but a sensible land use policy that limits the abrupt conversion of lands for short-term gains might avoid undesirable interactions between climate and land use change.

7.6 Implications for Interventions

This section discusses some of the implications of the findings on drivers for designing responses to ''undesired'' ecosystem change. While Chapter 9 discusses responses in much more detail, issues discussed in this chapter suggest some relevant conclusions when it comes to the design of good responses.

7.6.1 The Problem of Multiple Effects of Interventions

In assessing the effect of interventions on an endogenous driver, it is necessary to take into account the various interactions the driver experiences with other drivers. For example, improved market accessibility, often seen as both a response and a driver (see Biggs et al. 2004), has at least two counteracting effects. On the one hand, it can increase the income of smallholders. On the other hand, it can induce an increase in aspirations of wealth, or increase vulnerability of smallholders to livelihood shocks, thus putting greater pressure on ecosystems. Its net effect, however, depends on how other drivers, like cultural or institutional change, interact with improved market accessibility.

In principle, changing a single driver can bring about effects by all modes of interactions discussed earlier, that is, triggering, reinforcing, and constraining other drivers, sometimes as unintended side effects called ''externalities'' within the economic literature.

7.6.1.1 Triggering

The introduction of market mechanisms as a means of improving human-well being has often triggered other drivers of change (for example, in southern Africa and Altai-Sayan). Smallholders now depend more heavily on commodity prices, and thus on the world market, than before; in this way, market prices have become a (potential) driver for ecosystem change. The introduction of EU policies in Portugal has led to a high degree of dependence on decisions made at the European level, which may not in all cases lead to policies that are appropriate for managing ecosystems and their services effectively at the local level. Unintended effects of responses/drivers might eventually counteract the intended positive effects of the changes.

Both market integration and shifts in decision-making involve changes in a driver that is exogenous to local decision-makers (farmers, smallholders). The effect, however, is not restricted to changes in exogenous drivers made by decision-makers external to the specific scale of the assessment. The dependence on European-level decisions, for example, is also present at the national level in Portugal and it was indeed a national decision to adopt these regulations.

7.6.1.2 Reinforcement

The Tropical Forest Margins assessment revealed that the resettlement projects designed to release the pressures on the natural and social environment in the densely populated regions of coastal Southeast Asia aggravated land use change due to swidden agriculture, which is a main driver in the processes of deforestation in the tropical forest margins in this region. The same assessment also showed that in lowland Latin America infrastructure development by the state—motivated by an attempt to improve human well-being at the national scale—has also contributed to slash-and-burn agriculture in the lowlands and to pasture creation for cattle ranching by incoming largeholders.

7.6.1.3 Constraining

Changes in a driver can also constrain the effects of other drivers. If the constrained drivers were causing problematic changes in ecosystems and their services, this constraining side effect is positive, as it further counteracts a negative driver of change. Developing institutional changes to constrain urban sprawl is an example of this type of interaction (Sweden SU).

However, if the action in question is constraining the effects of a ''positive'' driver (that is, a factor that induces changes of ecosystems for the better) or releasing the constraints on ''negative'' drivers, the side effect counteracts the effects envisaged by the original action. Examples of this type of interaction were found in some community assessments, where changes in ecosystems sometimes developed due to constraints in the practice of traditional agriculture, often seen as being more sustainable than modern agriculture. Strategies to foster economic development in Western China seek to regulate local activities, thus constraining the application of traditional knowledge and techniques in the region.

BOX 7.1

Crises in Ecosystems

A crisis is a devastating event or syndrome, often considered surprising, that typically follows a prolonged phase of inappropriate action or inaction, possibly due to a lack of awareness of the underlying drivers of the problem at hand. Crises can drive change by serving as triggers for action once an ecological or social threshold is passed. Often, the ecosystem has reached such a compromised state that the range of possible interventions is limited. Depending on how the crisis affects stakeholders and decision-makers, a crisis can be very effective in sending a message that action needs to be taken to solve a problem. A crisis can provide a "clean slate" that allows a system to reorganize, or decision-makers or managers to operate amid a context of renewal, and possibly learn from their past actions. However, a crisis that is not well-managed can trigger further crises (that is, have a domino effect). In still other situations, crises, even when severe, do not result in learning.

A crisis may be a management or policy failure. In Stockholm, Sweden, pressure groups have used their social networks to preserve areas in danger of being exploited (Sweden SU). These groups provide an example of how self-organization arises in a time of a crisis. When a crisis occurs, space is created for renewal, reorganization, and novelty. The crisis may be changes in property rights, acidification of soils, resource failures, rigid paradigms of resource management, new legislation, or governmental policies that do not take into account local contexts (Folke et al. 2003).

In the district of Toco in the northeastern section of Trinidad's Northern Range, communities perceived a crisis in government plans to develop a port facility, which they considered would have been disruptive to their way of life without necessarily contributing appreciably to improving their well-being. As they were not consulted in the process and could not give input, the experience motivated the communities to formulate their alternative vision and plan for the district, to unite themselves in a community-based organization encompassing all the communities of the district, and to successfully resist the government plans.

A crisis may be a natural or environmental disaster. In Trinidad, more frequent and intensive floods in the city in recent years, including the suburbs which previously were not thought to be vulnerable, have led to an increasing emphasis on reforestation with rapid initiatives being taken. Recent discovery of sewage pollution in a water treatment plant has led to relevant agencies coming together to collaborate in taking remedial action (Northern Range).

A crisis may not always inspire a change in management. While certain individuals or groups may view a situation as a crisis, those who have the ultimate authority may be unaware of it or choose to ignore it, or take inappropriate or superficial measures to address it. Droughts in southern Africa in the 1990s that led to water shortages in the urban and relatively affluent Gauteng Province of South Africa were collectively considered a "crisis" that motivated the government to impose restrictions on water use, causing a reduction in the domestic consumption of water; the government even considered shutting off certain supplies (SAfMA Gariep). This represented a huge opportunity to change behavior and attitudes toward water use. However, when the rains came, the restrictions were lifted, allowing people to revert to their previous behavior. This is an example of a conditional crisis, brought about by changes in the apparent availability of an ecosystem service.

From these examples, it is evident that crises can serve as impetus for action. Sometimes this may lead to positive results, as in the case of Toco (positive from the point of view of the communities). Sometimes, the action may be hasty and not well grounded in an analysis of all the factors (for example, in the case of a decision to reforest without the proper analysis of where, why, with what species, etc.). While crises offer opportunities for action and for influencing action, the effectiveness of actions and the resulting winners and losers depend upon a range of factors.

While a crisis can create opportunity, much destruction and devastation may result before renewal can begin. Whether or not the ultimate effects of crises are positive, they can often be instructive for decision-making if they provide lessons on how and why crises occur. Scenarios can be a useful tool for improving understanding of events that lead to crises, because they help to identify a system's governing structures and processes. Changes in slow variables are most likely to catch communities and decision-makers off-guard because these variables may not be monitored or even carefully observed. While surprises are inevitable, a participatory scenario planning exercise can help decision-makers to understand the functioning of less well-known system components.

The examples illustrate that responses designed to affect a single driver can bring about a range of unintended side effects—either positive or negative with respect to ecosystem change. This produces trade-offs that have to be dealt with by a careful analysis of the system in order to assess the net effects of an intervention. (See Table 7.13 for a summary of how interacting drivers play out in the sub-global assessments.)

7.6.2 Intervening in Drivers: Multiscale Issues

All sub-global assessments distinguished between drivers that are under the control of the decision-maker addressed by the assessment (endogenous) and drivers that are not controllable (exogenous). As shown earlier, many drivers which were assessed as being exogenous at one scale are considered endogenous at another scale.

The multiscale property of endogenous versus exogenous characteristics of drivers suggests that in many cases a successful response needs to be coordinated across scales. Otherwise a situation can arise in which the incentives given at the local scale, for example to land users for resource conservation, are offset by other measures, such as prices or subsidies developed at the national scale, as was evident in some of the local assessments in southern Africa (Erin Bohensky, personal communication).

7.6.3 Adaptive Co-management of Social-ecological Systems

All ecosystems have a certain degree of resilience, which is the amount of change a system can withstand while retaining its structure and the variables and processes that control its behavior (Holling and Gunderson 2002). In other words, resilience refers to a system's capacity to be flexible (Redman and Kinzig 2003). Although originally developed for ecological systems alone, the concept is now also applied to social-ecological systems. The complex set of driver interactions is a substantial ingredient in the resilience of the overall system. For social-ecological systems, resilience

Table 7.13. Interventions in Interacting Drivers: Examples from Selected Sub-global Assessments

Sub-global Assessment	Interventions in Interacting Drivers
Altai-Sayan	The driver of environmental consciousness and behavior is public environmental education. Positive results may emerge in the next decade under a cooperative educational effort, particularly if the process is accompanied by successful small businesses in services and agriculture (where most local stakeholders are). ***Suggests that interventions must include stakeholder participation.***
Tropical Forest Margins	For policy intervention, it will be important to evaluate all the consequences of turning around certain drivers. Some of the underlying causes of deforestation, such as economic development and technological change, cannot be attenuated without negatively affecting the potential to improve the well-being of the population living in forest environments. Rather than being suppressed, these forces should be channeled toward a more sustainable use of ecosystem services. Policies should focus on the feedback mechanisms built into pathways of ecosystem change (e.g., deforestation), with an aim of influencing positive and negative feedbacks. The goal should be to quickly turn around deforestation trends once they have started. ***Suggests that interventions should be designed to take account of naturally occurring feedbacks.***
Caribbean Sea	Fish harvest technology adaptation and use, together with open access to the Caribbean Sea by international fishers, has led to overharvesting of fish stocks, which cannot be controlled because of the lack of a regional governance framework for fisheries. ***Suggests that it is difficult to intervene in interactions without effective governance.***
India–Western Ghats and Eastern Himalayas	Interventions have been directed at land use patterns through integrated farming systems (farming, animal husbandry, and forestry). The change in farming systems has been fairly successful because this provides a holistic approach to conservation and livelihoods. Population growth has been successfully reduced, as users saw the personal and social benefits of minimizing family sizes, birth control technology became easily accessible everywhere, and options emerged to secure the benefits previously provided by having many children. ***Suggests that integrated interventions can be successful.***
SAfMA	Regional scale initiatives such as the New Partnership for Africa's Development (NEPAD) are intended to enable more regional cooperation in the management of ecosystem services, through shared water agreements, regional food production, and trans-frontier conservation areas. However, the level of member states' participation in these initiatives, and their capacity to design and implement them, varies. Since democratic elections, legislation in South Africa has been aimed at achieving basic human needs and social equity, maintaining ecosystem services, and promoting economic growth. This requires interventions that are designed to address the interactions and synergies among these objectives. ***Suggests an emphasis on inclusive, multiscale, multi-objective interventions.***
Sweden KW	Interventions include the EU Water Framework Directive (basin-scale water management, multi-layer management, and different knowledge systems). By allowing subsidies to be used for cattle to graze flooded meadows under the Common Agricultural Policy, agricultural and ecological objectives have merged. ***Suggests a multisectoral approach to interventions.***
Sweden SU	The major direct driver of losses of ecosystem services is green area loss. Economic development, coupled with institutional mismatches for ecosystem management, and a lack of understanding of ecological support functions all indirectly drive green area loss. Interventions include (1) the Swedish strategy to achieve the targets of the CBD that places this responsibility on industry and society; (2) protected areas (natural and cultural); (3) stakeholder participation in policy-making; and (4) adaptive co-management of all areas, including buffer zones and weak links, not just the focal urban area. ***Suggests that a holistic approach to management that includes adjacent/supporting areas (buffer zones and links) is needed.***

strongly depends on the degree to which a system is capable of self-organization, learning, and adaptation to change.

Because drivers are a major human component of any social-ecological system, they are a strong determinant of the system's self-organizing capability. This can be seen, for example, in Sweden KW: the assessment defined a social-ecological system to be comprised of four major elements:

- the function and dynamics of an ecosystem;
- the management practices of this ecosystem;
- the knowledge system behind this management; and
- the institutions underlying this management.

The latter three elements are usually directly related to endogenous drivers, and include social capacity to adopt an ecosystem management approach, to cope with urban sprawl, increased flooding, or eutrophication.

The study of social-ecological systems leads to the concept of adaptive co-management, which, according to the Kristianstad assessment:

> *focuses on creating functional feedback loops between social and ecological systems. It relies on collaboration among a set of stakeholders operating at different levels, often in networks,*

from local users to municipalities to regional and national or supranational organizations. Adaptive co-management systems have been defined as flexible community-based systems of resource management tailored to specific places and situations supported by, and working with, various organizations at different levels. (Sweden KW, p.8).

In order to address the complexity of interactions among drivers, and between drivers and ecosystems, interventions need to be focused on changing the system. Interactions should be changed to promote the resilience of the overall social-ecological system.

7.7 Conclusion

The sub-global assessments revealed a richness and complexity among drivers of ecosystem change that is not found in the MA global assessment. Yet the results presented in this chapter give only a limited perspective on the overall information found within the sub-global assessments. The meta-analyses on the relationship between drivers' directness and controllability as well as between spatial and temporal scales are unprecedented, and as such valuable and illuminating. Yet their general validity is not ensured, as the set of sub-global assessments is not representative of the plurality of social-ecological systems.

The attempt to shed light on the interactions among drivers has to be read with care. The generalizations made in attempts to give a general picture of the processes identified in these specific assessments neglect important details of the sub-global processes of ecosystem change and related implications for human well-being. However, generalizations are necessary in a multiscale, complex world, where decision-making takes place at multiple scales and in the context of complex social-ecological systems.

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Chapter 8

Condition and Trends of Ecosystem Services and Biodiversity

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Main Messages ***173***

8.1 Introduction **173**

8.2 Condition and Trends of Ecosystem Services and Biodiversity: A Complex Issue **174**
8.2.1 Approaches Used in Assessing Condition and Trends
8.2.2 Challenges in Assessing Condition and Trends

8.3 Findings **182**
8.3.1 Biodiversity
8.3.2 Supporting Services
8.3.3 Provisioning Services
8.3.4 Regulating Services
8.3.5 Cultural Services

8.4 Linkages and Trade-offs among Ecosystem Services **194**
8.4.1 Examples from the Sub-global Assessments
8.4.2 Frameworks and Decision-making Tools to Analyze Trade-offs

8.5 Synthesis **198**

REFERENCES **200**

APPENDIX

8.1 Qualitative Assessment of Condition and Trends: Biodiversity and Provisioning, Regulating, Supporting, and Cultural Services in Selected Sub-global Assessments **202**

BOXES

8.1 An Inventory of Ecosystem Services: Downstream Mekong Wetlands
8.2 Economic Valuation of Services: Portugal
8.3 Qualitative Assessment of Condition and Trends of Ecosystem Services: Portugal
8.4 Heterogeneity of Condition and Trends: Tropical Forest Margins
8.5 Biodiversity Intactness: SAfMA Regional
8.6 Conservation Targets, Gap Assessments, and Conservation Status: SAfMA Gariep
8.7 The Ecological Integrity Index: Coastal BC
8.8 Supporting Ecosystem Services: China
8.9 Controlling Floods and Decreasing Sediment: Western China
8.10 The Cultural Importance of Ecosystem Services: SAfMA Gariep

FIGURES

8.1 Supply–demand Assessment of Food and Water Provisioning in Southern Africa (SAfMA-Regional)
8.2 Total Fish Production in Laguna Lake, Philippines, 1980–1996
8.3 Biodiversity Irreplaceability Values in Portugal per 10x10 Kilometer Cell*
8.4 Comparison between the Sub-global Assessments of Biodiversity Condition and the Amount of Native Habitat Remaining in the Ecoregions of the World*
8.5 Comparison between Freshwater Condition in the Sub-global Assessments and the Global Distribution of Human Population in 1995 Relative to a Threshold of Severe Water Scarcity*
8.6 Marine Animal Catches by Animal Type in the Caribbean Sea*

TABLES

8.1 Ranking of the Relative Importance of Ecosystem Services Using a Participatory Approach: SAfMA Gariep
8.2 Data Availability to Assess Ecosystem Services: Caribbean Sea
8.3 Land under Cultivation in Southern Africa: Various Estimates
8.4 Nature Tourism Numbers and Revenue: SAfMA Regional, 2000
8.5 ASB Summary Matrix for the Indonesian Benchmark Sites

*These appear in Appendix A at the end of this volume.

Main Messages

The sub-global assessments show that several ecosystem services are in fair to poor condition and declining. Despite some gains in the provisioning of food, water, and wood, the capacity of ecosystems to continue to provide these services is at risk in several locations; problems with provisioning services include deterioration of water quality, deterioration of agricultural soils, and incapacity of supply to meet demand. Some threats affecting regulating services are loss of forest cover, rangeland degradation by overgrazing (particularly in drylands), loss of wetlands to urban development and agriculture, and change in fire frequency. Problems with cultural services include loss of cultural identity and negative impacts from tourism. Biodiversity is decreasing due to the loss of habitats and the reduction of species population sizes. Species declining particularly fast include species with large body size, species occupying high trophic levels, and species that are harvested by humans.

In general, the assessments found the condition of water provisioning and biodiversity at global and sub-global scales to be congruent. However, in some cases, the sub-global assessments reported a poorer or better condition than the global findings for that region. Differences were due to the effects of drivers that were not picked up at the global scale, or to fine-scale heterogeneities missed in coarser-scale analyses at the global scale. There were more mismatches for biodiversity than for water provisioning because the concepts and measures of biodiversity were more diverse in the sub-global assessments.

Land use change is the most important driver for provisioning, supporting, and regulating services and for biodiversity. Some direct drivers of ecosystem change were also indicators of the condition of the service (for example, harvest pressure is an indicator of biodiversity). Indirect drivers control the patterns of demand for provisioning and cultural services, thus inducing changes in ecosystems. Tourism was found to have a negative impact on biodiversity in the Northern Range, SAfMA, Portugal, and Caribbean Sea assessments. While human controlled drivers play a major role in determining the condition of ecosystem services, local biophysical constraints such as climate and soils also limit the production of ecosystem services.

Clear trade-offs exist among ecosystem services. For example, a potential trade-off situation exists at one site in the southeastern part of the Gariep Basin, where biodiversity is totally irreplaceable and protein and caloric production are highly irreplaceable. The sub-global assessments, like the MA global assessment, found that an increase in provisioning services generally occurs at the expense of regulating services, supporting services, and biodiversity, or at the expense of the capacity of ecosystems to provide services to future generations. Trade-offs also occur among provisioning services such as between irrigated agriculture and freshwater provisioning.

Trade-offs among ecosystem services can be minimized. The studies of the Tropical Forest Margin assessment in Indonesia and Cameroon showed that a "middle path" of development involving smallholder agroforestry and community forest management for timber and other products is feasible. Such a path could deliver an attractive balance between environmental benefits and equitable economic growth.

New approaches were developed to demonstrate, communicate, and discuss these trade-offs with policy-makers. One was the Alternative to Slash-and-Burn matrix, where natural forest and alternate land use systems were scored against criteria reflecting the objectives of different interest groups in the Tropical Forest Margins assessment. Another was the use of a decision support tool, the Podium Model, to assess options for cereal-based food security and water availability in the Gariep Basin of southern Africa; this showed that expanding irrigated area alone, at large costs to water provisioning services, is unlikely to improve food security.

The sub-global assessments improved understanding of how human well-being depends on ecosystems, in several ways. Examples include inventories of ecosystem services (for example, 64 plant species used to extract biochemical substances were identified in Downstream Mekong); calculations of trade-offs among services (for example, between water conservation and food production in SAfMA); economic valuations of ecosystem services such as tourism, soil protection, run-off regulation, and carbon sequestration (Portugal), and lessons about the importance of cultural landscapes and biodiversity for local livelihoods (Bajo Chirripó and India Local).

The sub-global assessments used numerous and varied methods to assess the current condition and trends in ecosystem services. These methods included geographic information systems, remote sensing, inventories, indicators, economic valuation, and participatory approaches. Participatory approaches were useful in incorporating both scientific and local knowledge into the assessments. Because the sub-global assessments used different definitions and methods of assessing condition, the findings were not always comparable across assessments.

The different approaches used to assess the condition of ecosystem services reflected different interpretations of what is meant by the condition of an ecosystem service. Some assessments emphasized the ecological capacity of the system to provide the service (for example, Portugal) while other assessments emphasized the production and the demand for the service (for example, SAfMA) or equity of access to the service (for example, Sinai). Differing emphases were partially related to the socioeconomic development of the region being assessed: issues of equity and production versus demand were not the main focus of industrial-country assessments (Portugal, Sweden, Norway).

Several sub-global assessments applied novel approaches to the assessment of biodiversity. These include measures such as the Biodiversity Intactness Index (SAfMA), the Reef Condition Index (PNG), and the Ecological Integrity Index (Coastal BC). Each of these measures integrated indicators of different aspects of biodiversity condition into a single index, that could then be used to enhance the dialog on biodiversity with policy-makers and the public.

There is a need for long-term monitoring of the condition of all types of ecosystem services using comparable indicators. Limited data were available to assess the condition of regulating and supporting services. There is an overwhelming lack of historical data on the state of biodiversity in the sub-global assessments. In many locations, sub-global assessments collected data on the condition of ecosystem services for the first time; these data can serve as a baseline for future assessments. The lack of data and the spatial heterogeneity of the condition of ecosystem services led to uncertainty in the assessment of condition and trends of ecosystem services. The development of fine-tuned responses to the deteriorating conditions of ecosystem services will require a concerted effort at data collection and analysis at all scales.

8.1 Introduction

This chapter assesses the current state and recent trends in ecosystems and their services in the MA sub-global assessments. As of January 2005, 24 sub-global assessments had produced information on the condition and trends of ecosystem services. Of these, 16 were still on-going (Argentine Pampas, Bajo Chirripó, Caribbean Sea, Colombia, Down-

stream Mekong, India Local, Laguna Lake Basin, Northern Range, Portugal, PNG, San Pedro de Atacama, Sweden KW, Sweden SU, Tropical Forest Margins, Vilcanota, Western China). Three were completed (Coastal BC, SAfMA, and the pilot assessment in Norway), and five had only preliminary findings from pilot activities (Altai-Sayan, Eastern Himalayas, India Urban, São Paulo, Sinai). The chapter draws heavily on the state of assessment reports and final reports of the sub-global assessments, with additional information gathered through personal communication with the sub-global assessment teams.

The chapter is structured into four major sections. The first section provides a general overview of the methods and data sources used by sub-global assessments for assessing current condition and trends of ecosystem services, and looks at the complexity of undertaking such analyses. The second section collates robust findings from the sub-global assessments and identifies key uncertainties; it links the findings to condition indicators and drivers of change. The third section summarizes the sub-global findings on trade-offs and linkages between ecosystem services and biodiversity, and the final section integrates and analyzes the main results of the first three sections.

8.2 Condition and Trends of Ecosystem Services and Biodiversity: A Complex Issue

The MA conceptual framework (MA 2003) states that people perceive the condition of an ecosystem in relation to its ability to provide the services desired. This definition implies that different cultures may well have different perceptions of the condition of ecosystem services. Furthermore, the MA focuses not only on the production or ''flow'' of ecosystem services, but also on the sustainability of the use of these services, which can be thought of as maintaining the ''stock'' of natural assets. These concepts are simpler to apply to marketed services (Perman et al. 2003), which are mostly provisioning services, than to non-marketed services such as supporting or regulating services.

Current approaches for assessing condition and trends use a combination of methods and tools (Carpenter et al. 1998; Foster et al. 1998; Fuller et al. 1999). This section starts by illustrating the range of methods and data sources used by the sub-global assessments and then examines issues associated with synthesizing and comparing results across assessments.

8.2.1 Approaches Used in Assessing Condition and Trends

In order to understand changes in the maintenance of critical functions and the provision of essential services, assessments can use integrated historical and spatial reconstruction of ecosystems, such as historical records and databases, paleo studies, remote sensing, models, and expert knowledge. Briefly introduced here, these data sources and approaches are discussed at greater length in Chapter 2 of MA *Current State and Trends*.

8.2.1.1 Remote Sensing

Remote sensing data are usually obtained from satellite sensors and can be used to monitor Earth's surface and atmosphere on a regional and global scale (Burrough 1994; Peuquet and Marble 1990). Remote sensing allows for the assessment of large areas in a consistent fashion, something which is seldom possible through ground-based surveys, although ground-truthing is an essential component of the classification of remotely sensed images. The images generated through remote sensing can be used to derive data on land cover, land use, wetland distribution, land degradation, primary productivity, and other attributes of the land. Repeated observations of the same area are possible and allow for the assessment of trends in the above-mentioned attributes. Many sub-global assessments made use of remotely sensed data (Tropical Forest Margins, Western China, Downstream Mekong, Portugal, PNG, São Paulo, SAfMA, Norway, and Colombia). Western China was one of the few assessments to extract land cover and primary productivity data directly from satellite images; most assessments relied on already-classified land cover maps.

8.2.1.2 Geographic Information Systems

The analysis of disparate spatial data sets, comprising social, economic, and ecological data, is made possible through the use of geographic information systems. These disparate data sets can be combined in a GIS to generate spatially explicit results (in SAfMA, for example, GIS was used to examine where human demand for a particular ecosystem service exists and where that service is supplied). Sub-global assessments used GIS for tasks such as: integrating land cover information from different sources (for example, Tropical Forest Margins, Western China, Downstream Mekong, Portugal, PNG, SAfMA, Sweden SU, Norway, and Colombia); analyzing temporal changes in primary productivity (Western China) and land use (for example, Sweden SU); determining spatial characteristics such as distance, patch size, and shape (for example, Sweden, SAfMA); analyzing trade-offs between provisioning services and biodiversity (SAfMA Gariep); and providing a graphic interface with spatial models of ecosystem processes (Western China) and scenario outputs (SAfMA Regional).

8.2.1.3 Indicators

An indicator is a scientific construct that uses data to measure the condition of ecosystem services, drivers of change, or human well-being (MA 2003); it acts as a surrogate measure of more complex aspects of the reality being assessed. An indicator can simplify the multivariate nature of the attribute being measured into a single value, thus allowing for spatial and temporal comparisons between values. Indicators provide an effective means of communication with policymakers. Caution should be exercised when interpreting indicators, as they are simplifications of complex reality and might thus not capture all elements of the condition being measured (Bossel 1999). A bias toward easily quantified indicators may ignore some of the more important elements of the condition of ecosystem services, and temporal and

spatial scale mismatches are also potentially confusing. For instance, there is a potential disconnection between the production of a service and the sustainability of that production (as found in the Portugal assessment).

The sub-global assessments used a variety of indicators of the condition of ecosystem services. In general, these indicators can be divided into two types: indicators representing the current state of particular services, and indicators measuring the pressure from drivers that influence the condition of those services (discussed in greater detail later in this chapter). It was apparent from the sub-global assessments that there are far more data and indicators available for provisioning services and human well-being than for regulating, supporting, and cultural services.

8.2.1.4 Inventories

In the sub-global assessments, inventories can be broadly divided into biodiversity inventories, ecosystem service inventories, and natural resource inventories. (See Chapter 11 for a discussion of social inventories.)

The biodiversity inventory is usually composed of species lists, often including lists of endemic or threatened species, although some may include lists of habitats or vegetation types found in the ecosystem as well. These inventories do not reflect the entire biodiversity of a region and tend to focus on well-known species, flagship species or species of value within the ecosystem (Royal Society 2003). Information in these inventories is usually collected through field surveys.

Inventories of ecosystem services list all the types of services provided by given location, such as services extracted from a forest or all known regulating services provided by a wetland. (See Box 8.1.)

Biodiversity and ecosystem service inventories were widely used in the sub-global assessments and proved to be very useful in assessing the importance of various ecosystems, and their services, for human well-being. Some of these inventories were produced by the sub-global assessment teams; examples include Downstream Mekong, Tropical Forest Margins, and India Local (the latter produced biodiversity inventories collected by school children in the study area). Other sub-global assessments relied on existing inventories, such as those found in museum collections, atlas data, and the scientific literature (examples include SAfMA Gariep, Portugal, Sweden KW, and Norway).

A third type of inventory is a natural resource inventory. These inventories may include data on the locations and amounts of provisioning services such as water, timber, agricultural products, and fisheries. They are often conducted at a national scale and include national statistics on production; an example is the Global Forest Resources Assessment (FAO 2001). Not all sub-global assessments used this type of inventory; this could be due to the fact that the boundaries of the assessment areas and national boundaries often did not coincide. Sub-global assessments that used national or international natural resource inventories include SAfMA, Laguna Lake Basin, Colombia, and Portugal.

BOX 8.1

An Inventory of Ecosystem Services: Downstream Mekong Wetlands

Provisioning services

- Food: agricultural crops, livestock, wildlife, vegetables, fruit, honey, and spices.
- Provisioning of medicinal substances: 280 medical plant species have been identified, 150 of which are frequently harvested; some animals including reptiles and birds.
- Timber: timber for house frames, leaf stems for roofs and walls
- Fuelwood, resin, and fiber.
- Provisioning of bio-active substances: 16 plant species providing toxic products, 28 species providing color products, 21 species providing tannin.
- Fresh water.

Regulating services

- Alum soil regulation.
- Water purification and run-off regulation.
- Climate regulation.
- Disease regulation.

Cultural services

- Inspirational
- Birthplace of various traditional performances
- Ecotourism and recreation
- Cultural heritage

8.2.1.5 Ecological Models

Ecological models are simplified mathematical expressions that represent the complex interactions between physical, biological, and socioeconomic elements of ecosystems (Roughgarden 1998; MA 2003). A review of the types of models available can be found elsewhere (MA *Current State and Trends,* Chapter 2, and MA *Scenarios,* Chapter 4). To the extent that models are simplified representations of reality, they provide an important tool for filling gaps in existing data, quantifying the effects of management decisions on the condition of ecosystem services, projecting long-term effects of changes in ecosystem condition, and assessing the effects of individual drivers and scenarios on ecosystem condition and the supply of ecosystem services (MA 2003). They can also project the viability of specific species populations under future conditions, and help increase our understanding of the complex interactions between biophysical and socioeconomic components of ecosystems. The use of models is not simple, however, and requires location-specific data and validation, which are often time and resource intensive; many sub-global assessments therefore did not apply modeling techniques.

The Western China assessment used the Agroecological Zoning model to estimate the carrying capacity of land: this is the maximum number of individuals that can be supported by ecosystem services in a unit area assuming sustainable development (Western China). In the Tropical Forest Margins assessment, the CENTURY model was used for simulating the change of carbon storage for different land

use scenarios. Argentine Pampas used the Agro-Eco-Index model (Viglizzo et al. 2003) to incorporate data and calculate indicators of the environmental sustainability of agriculture. The SAfMA Gariep assessment made use of the PODIUM model (Kamara and Sally 2002) to assess trade-offs between food and water provisioning services. SAfMA Regional made use of the IMAGE model to predict land cover change under different scenarios.

8.2.1.6 Participatory Approaches and Expert Opinion

The sub-global assessments made extensive use of participatory approaches, with participants ranging from scientific experts at regional scales to community members at local scales. (See Chapter 11 for a more detailed discussion of local stakeholder involvement in participatory data collection.) These approaches allowed for the collection of forms of data not available in the literature, for example, from traditional and indigenous knowledge at the local scale. At broader scales, data gaps in the conditions and trends of various ecosystem services could be filled through workshops where experts and stakeholders were asked to qualitatively assess the condition of ecosystem services.

The assessments used several techniques of participant involvement, including focus group workshops, semi-structured interviews with key informants, interactive theater, participatory mapping, ranking and scoring, trend lines, problem trees, role-playing, and seasonal calendars (for a discussion of these methods see FAO 2005). Portugal, SAfMA, and Norway made use of participatory ranking and scoring for the condition and trends of ecosystem services and biodiversity. In the SAfMA Livelihoods assessment, community members were asked to rank various ecosystem services and their importance in the region. (See Table 8.1) Community members were also asked to use the number of stones to score the water quality in various areas under different forms of tenure over the last 40 years.

The use of participatory approaches, different types of knowledge and data, and local and regional expert input was one of the strengths of the sub-global assessments. (See Chapter 5.) Using these methods involved the development of new frameworks, methods of assessment, and systems of peer review in order to include these forms of knowledge and data as an input to assessments. In addition, it encouraged wide stakeholder involvement and buy-in. (See Chapter 6.)

Table 8.1. Ranking of the Relative Importance of Ecosystem Services Using a Participatory Approach: SAfMA Gariep.
Ecosystem services ranked by the amaXhosa people of the Eastern Cape, from highest (1) to lowest (11).

Ranking	Ecosystem Service
1	mountain water
2	cultural species
3	fuelwood
4	livestock
5	medicinal plants
6	building materials
7	river water
8	agricultural crops
9	*imiFino* (wild vegetables)
10	honey
11	wild fruits

8.2.1.7 Economic Valuation

Economic valuation is a technique used to place a value on the benefits derived by humans from ecosystems and their services. This value is expressed in monetary terms in order to measure the benefits of a wide variety of services using a common metric. Although this metric is an economic one, it does not imply that only ecosystem services that generate direct monetary benefits can be valued. In fact, much of the recent work on economic valuation of ecosystem services has focused on how to value services that are not marketed (Bingham et al. 1995; Boumans et al. 2002; Costanza et al. 1997; DeGroot et al. 2002; Desvouges et al. 1998; Freeman 1993). Several techniques are used in the economic valuation of services (these techniques are summarized in Chapter 2 of MA *Current State and Trends*).

Although the methods and importance of economic valuation were highlighted in the MA conceptual framework (MA 2003), few sub-global assessments used this method of assessment. Exceptions included Portugal, where several marketed and non-marketed ecosystem services of forests were valued (see Box 8.2), and SAfMA Regional, which estimated the economic value of tourism as a recreational service.

Reasons for the lack of economic valuation in the sub-global assessments are varied but appear to relate to a lack of capacity, time, and the absence of markets. It is important to note that the assessment of non-marketed services (particularly supporting and regulating services is possible but time-consuming), and the time frames of the sub-global assessments were relatively short. In addition, some assessments and their users were not convinced of the benefits of assessing economic value compared to other measures of human well-being (particularly in rural areas where markets for many ecosystem services do not exist).

8.2.2 Challenges in Assessing Condition and Trends

This section examines different ways in which sub-global assessments assessed condition and trends, and then discusses the associated challenges in terms of spatial heterogeneity, fluctuations in time, lack of data, and expressing uncertainty.

8.2.2.1 Defining and Assessing Condition and Trends

In general, the sub-global assessments analyzed the condition of ecosystem services in a qualitative manner, sometimes supported by quantitative data. For instance, the Downstream Mekong assessment described the food products cultivated in the region and also gave time-series data for these products for the last decade. The India Local assessment described the recent history of the forest in the region. The Laguna Lake Basin assessment described the declining lake water quality during the decade 1990–99,

BOX 8.2

Economic Valuation of Services: Portugal

In 1998, the forestry sector represented about 3% of Portugal's GNP and 11% of its exports. Among the fifteen European Union members at the time (EU-15), only Finland and Sweden had forestry sectors with a larger role in the respective national economies. This statistic includes only provisioning services; an assessment of the value of some other ecosystem services provided by forests suggests that their inclusion would increase the economic value of forests in Portugal by at least 20%. Furthermore, the forestry sector employs over 228,000 people, about 5.14% of total employment (Portugal).

Economic Value of Forest Goods and Services, 1998 (Carvalho Mendes 2004)

Forest Commodity/Service	**Value** *(million euros)*
Timber	257.6
Cork	221.9
Total, timber goods	**479.5**
Resins	13.1
Honey	5.6
Fruits	41.2
Wild mushrooms	32.5
Aromatic and medicinal plants	1.9
Game	58.7
Fodder	125.2
Acorn forage	6.7
Scrubland and heathland forages	17.8
Total, non-wood goods	**302.7**
Recreational use	5.9
Carbon sequestration	26.5
Agricultural land protection	75
Water resources protection	29
Landscape aesthetic value	20.1
Total, environmental services	**156.5**
Total, forest goods and services	**938.7**

which resulted in declining biological productivity. These descriptions tended to emphasize drivers of ecosystem change and the trends of certain indicators such as food production.

Some assessments complemented these descriptions with an overall qualitative ranking of the condition of the ecosystem service, relative to some baseline (examples include Portugal, Norway, Trinidad, Caribbean Sea, Altai-Sayan, and San Pedro de Atacama). The overall condition of the service was reported by ranking the condition on a scale, which ran in most cases from 1 (Bad) to 5 (Excellent). These qualitative rankings were based on expert opinion, often gathered through participatory approaches. (See Box 8.3.) This method was later adapted at a working group meeting of the sub-global assessments, where information from a knowledge market was used to derive a qualitative ranking of the condition of the ecosystem services in each sub-global assessment. (See Appendix 8.1.) Such qualitative rankings can have the limitation of reflecting the perceptions of the experts doing the assessment, particularly when there is little data to support the rankings made.

One difficulty faced by the sub-global assessments was the lack of data to serve as a baseline for the analysis of condition. The Norway assessment evaluated the current condition of ecosystem services relative to their condition 100 years ago, but when historical data are not available, as is the case in many developing countries, seeking to establish this kind of baseline is impractical. In fact, many assessments collected data on ecosystem service condition in the study areas for the first time; this information can serve as a baseline for future assessments of condition.

One alternative to using a temporal baseline is to use a baseline that is spatially segregated from the area being assessed. For example, the Tropical Forest Margins assessment compared its results to the conditions found in natural and undisturbed forest. The Portugal assessment resorted instead to a conceptual baseline, defined as the current capacity of the ecosystem to provide a service, relative to the level at which the service could be maximized in a sustainable way. Another approach is to compare the value of an indicator to some standard or normal value. For instance, desired and actual values for indicators of water quality are given in the Laguna Lake Basin assessment; based on those indicators, it is clear that the water in the Laguna Lake is not suitable for drinking and its fishery productivity is threatened. Finally, the condition of a service may be analyzed relative to the capacity of the ecosystem to respond to the local demand for the service; the supply-demand approach was widely used in SAfMA. (See Figure 8.1.)

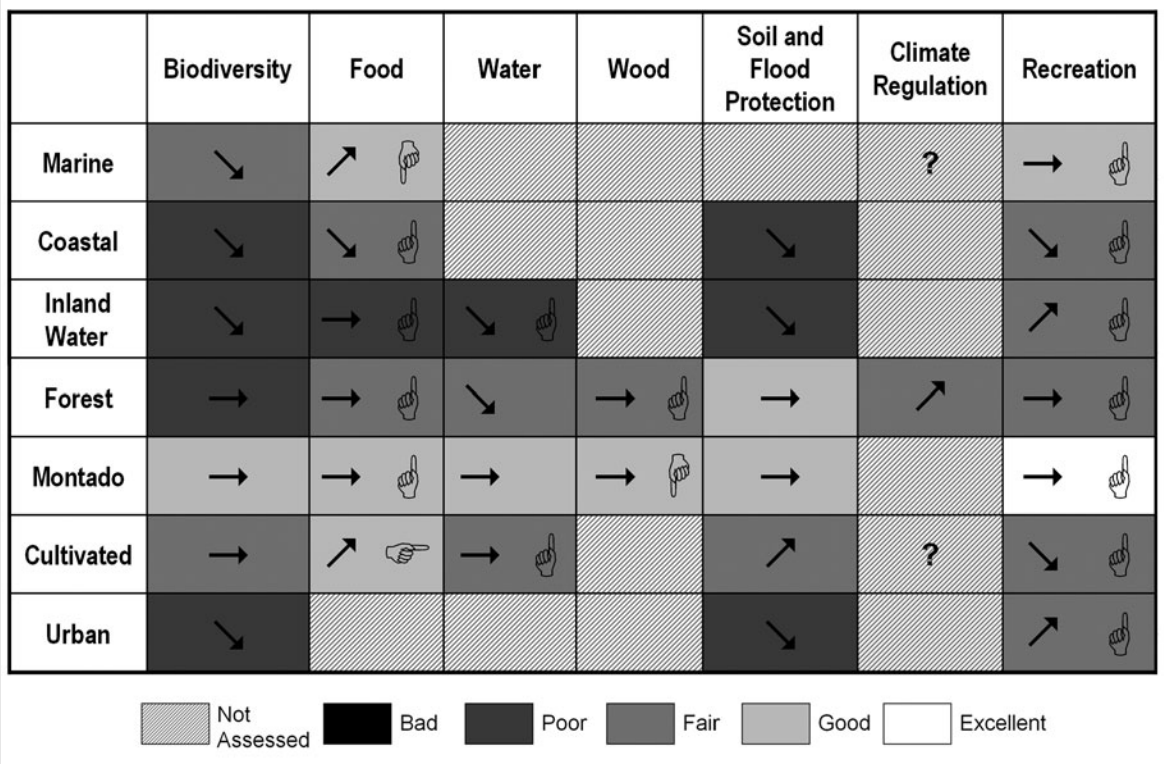
The supply-demand approach has the advantage of being easily quantifiable and communicated to decision-makers, but it can fail to detect deterioration or improvements in the capacity of the ecosystem to continue to provide the service in question. For instance, for provisioning services, the Portugal assessment reported both trends in the ecological capacity of the system to provide the service, and trends in the production of the service itself. These two trends are distinct and can differ: while marine fish landings have diminished in Portugal recently, stock levels have been improving (Portugal). Another limitation of the supply-demand approach is that it ignores spatial transfers of services. For instance, in the Gariep Basin, there are extensive systems of water transfer and food distribution so that even where supply is less than demand, overall demand may be met (SAfMA Gariep). Nevertheless, even where these transfer systems exist, the supply-demand approach reveals that: (1) access to services and security of access are also important and (2) the costs to ecosystems of these transfer systems (particularly of water) can be high and may threaten longer-term security of supplies.

Not only did the methods of assessing condition vary among assessments, but so too did the time frames over which trends were assessed. The Portugal assessment standardized trends to look 40 years backwards and 10 years forward. Some assessments took a particular year as the start of the trend analysis; often it was a year associated with a political change and thus a change in the ecosystem man-

BOX 8.3

Qualitative Assessment of Condition and Trends of Ecosystem Services: Portugal

In the Portugal assessment, a joint workshop of the assessment team and users was dedicated to a qualitative assessment of the condition and trends of ecosystem services. The condition of services was assessed according to five categories ranging from *bad* to *excellent,* and was defined as the current capacity of ecosystems to provide the service relative to the level at which the service could be maximized in a sustainable way. Two types of trends are shown: *arrows* indicate the trends in condition (the ecological capacity of the system); *hands* indicate the trends in production for provisioning and cultural services. Some services were not assessed because they do not occur or have only marginal importance. Question marks indicate services that would have been assessed if data were available.



agement regime. The Papua New Guinea assessment used the date of independence, 1975, as a reference point, while SAfMA Gariep used the transition to democracy in 1994 in some of their analyses. However, most assessments that had some form of trend information were constrained by the available data, and even within one study area the trend period could vary widely. For instance, in the Laguna Lake Basin assessment, the data used for trends in water quality started in 1990, while the data for trends in fish productivity started in 1963. In the Caribbean Sea assessment, the time frames for data on twelve ecosystem services varied widely. (See Table 8.2.) This variation in data made the comparison of condition and trends among ecosystem services or among sub-global assessments difficult.

8.2.2.2 Spatial Heterogeneity

Heterogeneity among the condition of services in different areas of each assessment was high. Spatial heterogeneity was found in local, sub-national, national, and regional assessments. For instance, in SAfMA Gariep, the results in water quality differed between two types of land tenure; using a nearby state forest as a benchmark, people at Machibi village reported that during the past four decades, water quality on community land had deteriorated compared to that on state land.

The Bajo Chirripó assessment provides an example of heterogeneity at the sub-national scale; there were differences between the condition of the midlands and uplands, managed by the Cabécar indigenous population, and the condition of the lowlands managed for agriculture and livestock production, owned by non-indigenous people and livestock companies. In the midlands, there was a decrease of some game species and selective logging of trees with timber value. This poaching and logging took place at a large scale before the lands were returned to the indigenous populations in the 1970s. Today, about 90% of the midlands and uplands are covered by forest, which allows the local population to benefit from ecosystem services such as water provisioning and cultural traditions associated with sacred places. In contrast, in the lowlands, there is not much forest left, and the waters from rivers and wetlands are polluted, with large decreases in the populations of crocodiles, caimans, fish, and birds.

Different ecosystems provide particular bundles of ecosystem services and vary in their response to human pressure. This has to be taken into account when making

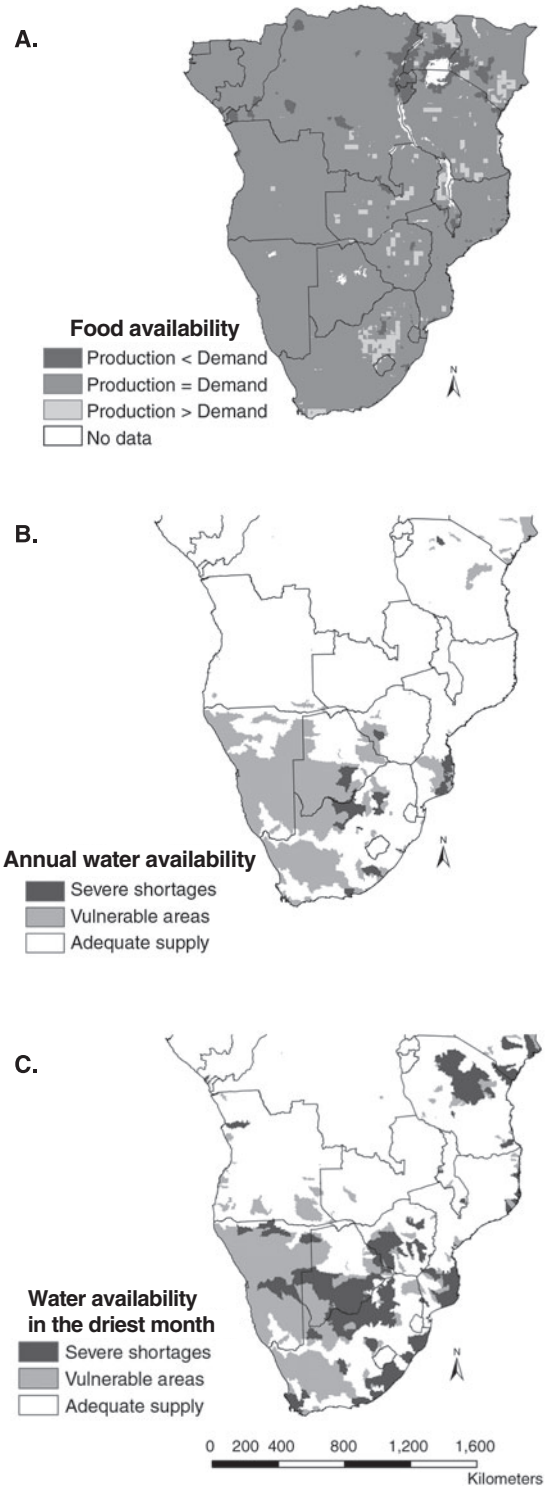


Figure 8.1. Supply–demand Assessment of Food and Water Provisioning in Southern Africa (SAfMA-Regional). Although the region as a whole is approximately self-sufficient in staple crops (maize, sorghum, and millet) and water in good years, the spatial pattern of food and water supply does not match demand, resulting in shortages in certain areas.

Table 8.2. Data Availability to Assess Ecosystem Services: Caribbean Sea

Ecosystem Service	Time Frame Evaluated
Fish production	1950–2000
Desalinated water	1992–2000
Live coral exports	1997
Oil and gas	1990–98
Beach sand removal	sporadic
Mangrove production	1993–99
Coral reef cover	1997–2002
Seagrass production	1993–99
Water quality	sporadic
Shoreline stabilization	sporadic, 1985–94
Tourism	1990–2001
Climate regulation	1950–2000

comparisons of the condition of services across different ecosystems. Heterogeneity at the national scale in the condition of services across systems is clearly illustrated in the Portugal assessment, with most services in the *montado* system in better condition than in the forest system. Similarly, in the Altai-Sayan assessment, services provided by forests are in better condition than services provided by grazing lands. Even within a given system, the condition of services can vary significantly.

Assessments conducted across more than one country showed high levels of heterogeneity due to different ecological, social, economic, and political drivers in those countries, which result in dissimilar land use and ecosystem management practices. For example, SAfMA Regional, which covered countries south of the equator in Africa, showed very different rates of forest loss in the region (ranging from 0.1% to 0.7% per annum). The Tropical Forest Margins assessment, where the humid tropical broadleaf forest biome is being assessed through several benchmark sites on three continents, is perhaps one of the best cases to illustrate the heterogeneity found within an assessment. (See Box 8.4.)

These results have three implications. First, when the condition of a service is expressed using a mean value across the entire assessment area, there is a tendency to derive intermediate values for the condition of all ecosystem services. Second, it is clear that responses based on these mean values would be inappropriate; instead responses should be considered at the finest scale appropriate. Third, assessments that span several ecosystems have to deal with heterogeneity among the different ecosystems, and within each ecosystem as well.

8.2.2.3 Fluctuations in Time

The analysis of a trend over a period of time is often complicated by fluctuations in the condition of the service. For instance, in the Caribbean Sea, fish landings peaked in the mid to late 1990s, but have since declined by about 33%. In the Laguna Lake Basin, fish production from open water fluctuated from 1963 to 1996 but showed an overall declin-

BOX 8.4

Heterogeneity of Conditions and Trends: Tropical Forest Margins

Not only does the condition of ecosystem services provided by the tropical forest biome vary dramatically across assessment sites, but it also varies within each assessment site. This heterogeneity reflects the irregular pattern of deforestation and land use change at the tropical forest margins, and the importance of the scale at which the assessment is conducted. If the Tropical Forest Margins assessment had been conducted only at Yaounde and Lampung (where there has been considerable loss of forest cover and the current land use systems focus on annual cropping) or only at Acre and Ebolowa (where forest is still the predominant land cover type), the findings of the assessment would have been quite different. This example stresses the importance of scale in designing, conducting, and reporting an assessment: to be representative, the area in which an assessment is conducted must attempt to include the full range of condition of the ecosystems and their services.

Condition of Ecosystems Services at the Tropical Forest Margins Sites, on a scale from 1 (bad) to 5 (excellent)

	Plant Biodiversity	Soil Nutrients	Carbon Sequestration	Fresh Water	Flood Protection	Food	Fuelwood
Brazil							
Acre	4	4	5	5	5	5	5
Rondonia	2	3.5	3	5	5	5	4
Cameroon							
Ebolowa	5	5	4	5	5	5	4
Yaounde	3	4	3	5	5	5	3
Indonesia							
Jambi	4	4	4	5	?	5	3
Lampung	1	2	2	5	?	5	1

ing trend at an average rate of 2.9% per year over a 33-year period; this decline has been generally attributed to declining water quality. In the 1970s, the Laguna Lake Development Authority introduced aquaculture, which first increased fish production, reaching its peak in 1984, after which a decline was again noted. (See Figure 8.2.)

These two cases illustrate the problems associated with using a single trend to describe changes in a service over time. One possible approach is to report both the trend and the size of the fluctuations. Another approach is to shorten the window of analysis to one in which the trend is linear (likely to be more relevant for short time projections). The window suggested in the MA conceptual framework (MA 2003), 40 years into the past and 10 years into the future, can be too long for services that evolve over shorter time scales. The choice of approach will depend on the goal of the assessment. For instance, when the goal is to compare response options, it is convenient to assess the trend in a time window similar to the time scale of the responses being considered.

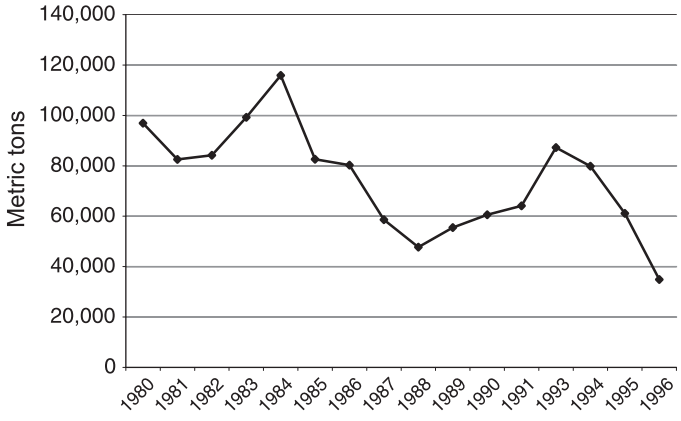


Figure 8.2. Total Fish Production in Laguna Lake, Philippines, 1980–1996. Data for 1992 was not reported.

8.2.2.4 Lack of Data

One of the most important weaknesses identified by sub-global assessments was the lack of comprehensive data in the study areas with which to assess the condition and trends of ecosystem services. Some sub-global assessments dealt with gaps in data by performing primary data collection. Alternatively, assessments resorted to expert opinion or excluded certain aspects from the assessment.

Supporting services were not thoroughly assessed in most sub-global assessments. (See Appendix 8.1 and Chapter 3.) This gap is of concern as the condition of supporting services has direct implications for the condition of most other services. Regulating services such as climate regulation and run-off regulation received more attention, but were still not assessed in several sub-global assessments. In contrast, provisioning services are easily conceptualized, quantified, and evaluated (MA 2003); almost all sub-global assessments included food and water provisioning in their analyses. Cultural services were relatively well assessed, especially tourism. Tourism is an important component of the economies of many of the sub-global assessments' study areas and data were readily available. Other elements of cultural services such as spiritual and aesthetic services were not as well assessed. Biodiversity was assessed by most sub-global assessments, but in a limited fashion, as data were available on current species composition or current extent of ecosystems, but trend data were rarely available.

Many assessments found that data were not uniformly available across the area studied. This was particularly the case for sub-global assessments that covered more than one country (for example, SAfMA Regional, Tropical Forest Margins, and Caribbean Sea). In some cases, sub-global assessments resorted to modeling to fill gaps in the data sets. For instance, species occurrence data are often biased toward areas close to urban centers, roads, and nature parks. The Portugal assessment filled the gaps in species data using realized niche models (Thuiller et al. 2003).

Another problem is the comparability of data sets across sub-global assessments. Issues include different techniques used to collect the data, varying scales of data collation, and differing dates, concepts, and definitions. SAfMA Regional found that using different data sets to assess area under cultivation resulted in different estimates. (See Table 8.3.)

8.2.2.5 Expressing Uncertainty

In addition to uncertainty in the assessment of ecosystem services created by spatial heterogeneity, lack of data, and fluctuations in time, uncertainties also arise from the drivers influencing those services. Uncertainties in the evolution of drivers such as governmental policy, climate change, technological development, and limited understanding of how drivers impact ecosystem functioning, propagate to uncertainties in the assessment of trends of ecosystem services.

Qualitative assessments by experts, scientists, community members and other stakeholders provided information and classifications of ecosystem condition for most sub-global assessments, but the uncertainty of qualitative assessments is difficult to quantify. Few sub-global assessments provided indications of the uncertainty associated with estimates of the condition of each ecosystem service. Exceptions include the Caribbean Sea and San Pedro de Atacama which ranked uncertainty on a qualitative scale from 1 (uncertain) to 3 (very certain). An alternative approach was followed by the Norway assessment, which listed the data quality issues associated with the assessment of each service, such as unknown variables or effects, data reliability, and gaps in the data.

Table 8.3. Land under Cultivation in Southern Africa: Various Estimates. The area estimated to be under cultivation in southern Africa varies considerably among different data sources (SAfMA Regional). The "core" areas given by the Global Land Cover Characteristics Database (GLCDD) of the International Geosphere-Biosphere Programme and the Global Land Cover (GLC) 2000 product are comparable to the areas given by MODLAND (land validation of MODIS satellite data), the Southern African Development Community (SADC) Land Cover Database, and FAO's Land Cover Classification System. The "total" areas include areas classified as cropland/natural vegetation mosaics, and therefore represent an upper estimate of the total area affected by cultivation.

	GLCCD IGBP				GLC 2000 Africa				MODLAND		SADC LC		FAO Statistics 2000	
	1,000 sq. km. core	percent	1,000 sq. km. total	percent	1,000 sq. km. core	percent	1,000 sq. km. total	percent	1,000 sq. km.	percent	1,000 sq. km.	percent	1,000 sq. km.	percent
Angola	63	5	127	10	48	4	49	4	28	2			33	3
Botswana	27	5	119	21	36	6	36	6	20	4			4	1
Burundi	1	4	17	61	9	33	9	33	6	12			13	45
Congo Rep.	5	1	13	4	2	1	14	4	5	1			5	1
Democratic Rep. of Congo	65	3	244	10	8	0	123	5	27	1			79	3
Equatorial Guinea	0	2	5	19	0	0	4	13	0	1			2	8
Gabon	6	2	20	7	0	0	12	4	3	1			5	2
Kenya	39	7	112	19	53	9	59	10	60	10			45	8
Lesotho	1	2	8	27	3	10	3	10	2	5	7	23	3	11
Malawi	23	19	29	25	31	26	31	26	12	10	59	50	22	19
Mozambique	219	27	282	35	71	9	73	9	19	2	48	6	41	5
Namibia	10	1	68	8	3	0	3	0	3	0			8	1
Rwanda	1	6	12	46	13	48	13	49	8	29			12	44
South Africa	150	12	462	38	134	11	138	11	92	8	144	12	157	13
Swaziland	11	66	12	67	0	0	0	0	5	31	4	20	2	11
Tanzania	221	23	358	38	178	19	178	19	74	8	101	11	50	5
Uganda	62	26	85	35	67	28	70	29	41	17			70	29
Zambia	114	15	256	34	64	8	64	8	59	8			53	7
Zimbabwe	160	41	211	54	119	30	119	30	26	7	107	27	34	9
Region	**1,178**	**11**	**2,442**	**23**	**842**	**8**	**998**	**9**	**494**	**5**			**634**	**6**

8.3 Findings

8.3.1 Biodiversity

The MA adopted the Convention on Biological Diversity's definition of biodiversity: the variability among living organisms from all sources including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part, including diversity within and among species and diversity within and among ecosystems (MA 2003). This definition of biodiversity is very broad, and the sub-global assessments tended to tackle particular components of biodiversity. For instance, the Sinai assessment focused on the diversity and abundance of medicinal plants, the Portugal assessment focused on the species diversity of selected taxonomic groups and on the extent of native forest, and the Caribbean Sea assessment focused on the remaining cover of live coral.

8.3.1.1 Drivers

Habitat loss was one of the most studied drivers in the assessment of biodiversity condition, with several assessments basing their results on land cover information derived from remote sensing data (Tropical Forest Margins, Western China, Downstream Mekong, PNG, SAfMA, Norway, Laguna Lake Basin, and Colombia). In fact, many sub-global assessments used the conversion of natural land cover to other forms of land use (for example, cultivation and pastures) as an indication of the condition of biodiversity. Other impacts of land cover change are fragmentation and degradation of the remaining natural habitat, which are often linked to losses of biodiversity. Fragmentation and its impacts on biodiversity were not assessed in detail by the sub-global assessments.

Degradation of ecosystems through overgrazing (a form of overexploitation) was evaluated in several of the sub-global assessments (Altai-Sayan, Argentine Pampas, and SAfMA Regional). In the Northern Range assessment, the overutilization of natural resources was identified as an important driver where the most sought-after timber species are no longer available and new species are now being harvested. The Western China assessment highlighted that hunting of wildlife and exploitation of plant species have had significant consequences for biodiversity, including the extinction of the Caspian Tiger (*Panthera tigris virgata),* Przewalski's horse (*Equus przewalski*), and the Saiga Antelope (*Saiga tatarica*).

The impacts of introduced alien organisms include altering the structure and function of ecosystems, as well as local and global extinctions of indigenous species. Some alien organisms thrive in the new environment and spread rapidly, becoming invasives. The Portugal assessment reports that one of the worst alien invasives in the country is the tree *Acacia sp.,* which is very costly to control or remove. But plantations of alien species can be a problem even when those species do not become invasives. For instance, in Portugal *Eucalyptus globulus* plantations have low biodiversity in comparison with native oak forests, and when poorly managed have negative impacts on soil and water resources. The Downstream Mekong assessment reported significant numbers of alien species, including decorative and food plants, industrial crops providing oil and fiber, and other accidental introductions impacting on both biodiversity and food production. In South Africa, 503 alien plant species are classified as harmful, invasive, or pests (SAfMA Regional). Invasive alien plants have reduced water flow by 10% (Görgens and van Wilgen 2004; SAfMA Regional), and in the Cape Floristic Region, they have resulted in total losses of ecosystem services of more than $100 million per year (Turpie et al. 2003; SAfMA Gariep). The cost of controlling invasive plants in South Africa is estimated to be about $100 million per year (SAfMA Gariep).

Two additional direct drivers of ecosystem degradation were levels of pollutants in water and air (Laguna Lake Basin, Coastal BC, SAfMA Gariep). Major sources of pollution entering the river systems of Laguna de Bay are domestic wastes (the largest source), food processing plant wastes, livestock wastes, chemical manufacturing spillage, various industrial effluents, fertilizers and pesticides from agricultural runoff, and eroded soils from the watersheds, which affect the tourism and fish production services of the lake (Laguna Lake Basin). Laguna de Bay offers examples of the impacts of eutrophication on lakes and their services.

Many sub-global assessments highlighted climate change as an important direct driver of change in biodiversity condition; however, much of the evidence was anecdotal and only in a few cases were scientific studies referenced. SAfMA Regional reported on climate change impacts to coral reefs, plant species distributions, and tree cover expansion into grassland and savannas. SAfMA Gariep projected that flagship protected areas may lose some of their current species by 2050. The Altai-Sayan assessment reviewed existing literature and determined that there is inconclusive evidence that changes in the tree line are related to climate change. The Caribbean Sea assessment reported coral bleaching and sea temperature change.

Of interest is the role of tourism and recreation as an indirect driver of change in biodiversity condition. Although tourism is often put forward as a way of promoting both conservation and development, it was advanced by many sub-global assessments as a driver of decreases in biodiversity condition (Northern Range, SAfMA Regional, Portugal, Caribbean Sea). This is particularly the case in coastal areas, where tourism infrastructure development destroys sensitive coastal habitats and decreases landscape value, while wastewater affects marine life and water quality (Portugal, Caribbean Sea). The intensive religious use of some areas can also introduce threats to biodiversity, as was found in the India Local assessment (India Local), despite the known importance of sacred groves for biodiversity conservation (Ramanujam and Cyril 2003).

Other indirect drivers include economic and governance factors. For example, the Northern Range assessment highlighted that inequitable distribution of wealth has led to increasing numbers of people seeking low-income housing on hillsides, especially in close proximity to urban areas. This in turn has led to deforestation and the subsequent degradation of land. The Colombia assessment reported

that direct correlation was found between indicators of economic activity and indicators of quality of life in the coffee-growing region, where municipalities with greater economic activity also showed higher levels of quality of life. Coffee production has increased the rural employment rate, but it has also led to significant deterioration in biodiversity condition through ecosystem degradation and natural vegetation loss. In the future, the minimization of biodiversity loss will depend on the expansion of farming practices that are biodiversity-friendly, such as traditional shaded coffee (Moguel and Toledo 1999), and on the protection of forest fragments in the rural landscape (Ricketts et al. 2001). Some sub-global assessments also cited ineffective and uncoordinated land use planning as the main reason for the poor condition of biodiversity, since this can lead to overexploitation of natural resources, pollution, and the introduction of alien invasive species.

The Northern Range assessment identified cultural and behavioral changes as indirect drivers of change in biodiversity condition. The assessment found that in places where there is inadequate information and understanding about the relationship between human activities and their impacts on ecosystem services, culture and behavior may exacerbate driving forces like land use change and overexploitation of resources.

8.3.1.2 Indicators

There are many possible measures of biodiversity condition and trends, and no strong consensus as to which are the best measures to use. (See MA *Current State and Trends,* Chapter 4). Most sub-global assessments, as well as the global assessment, focused on assessing the condition and trends of particular species and habitats.

Our knowledge and data on species distribution are incomplete, particularly in the tropics (MA *Current State and trends,* Chapter 4). Therefore, field surveys should target selected groups of species that may give indications of the overall condition of biodiversity. Examples include:

- threatened species (India Local, SAfMA Gariep, Portugal),
- invasive species (Downstream Mekong, SAfMA Regional, Laguna Lake Basin),
- indicator species linked to some particular element of biodiversity condition (for example, pioneer species),
- sensitive species that react to changes in the environment before other species,
- species of economic importance that can be exploited and even overexploited in unmanaged systems (India Local),
- nuisance and pest species as ecosystem disservices (India Local),
- flagship species (for example, the Western China assessment studied the impacts of land cover change on the Giant Panda, *Ailuropoda melanoleuca*), and
- species belonging to functional groups (Tropical Forest Margins), which are species particularly related to ecosystem processes and thus are essential to the production of ecosystem services (MA *Current State and Trends,* Chapter 11).

Simple species lists (or species inventories), and associated measures such as species richness and diversity are in most cases inadequate as measures of biodiversity condition and trends. Indicators such as the proportion of threatened species or the percentage cover of invasive species can be used, but a deeper understanding of the condition and trends of biodiversity can only be gained with time series data for these species lists. This information can then be used to calculate changes in geographic ranges and quantities (Ceballo and Ehrlich 2002; Thomas et al. 2004). For example, an increase in the abundance of alien invasive or pioneer species could indicate a disturbed ecosystem, while a decline in the numbers of a sensitive species would be indicative of some environmental change. Although species lists are quite common for many regions of the globe, these lists are rarely collected in a periodic and consistent way. The lack of historical data for population sizes is even greater. In the cases where historical data were not available, some assessments used expert opinion on the trends in species numbers (examples include Portugal and Sinai).

Local inventories of species can also be a method for engaging the community in the assessment. For example, in the India Local assessment, schoolchildren and teachers conducted nature studies in one or two square kilometer zones around their schools. The students recorded the various landscape element types and prepared an inventory of local plants and animals (India Local).

Sub-global assessments did not restrict their attention to biodiversity at the species and population levels, but also assessed the condition of biodiversity at the ecosystem and biome level, using a variety of methods including:

- linking species data to particular ecosystems, that is, numbers of threatened species per ecosystem (Portugal);
- assessing land cover and land cover change where ecosystems with high levels of converted land cover or rapid change in land cover can be highlighted (Western China, SAfMA, Tropical Forest Margins, Laguna Lake Basin)–in this case the indicator of condition is also the direct driver of ecosystem change; and
- identifying protected areas on the assumption that ecosystems with significant protected area coverage have biodiversity in good condition (SAfMA Gariep).

Protected area coverage has limited value for assessing biodiversity condition because many protected areas exist only on paper and do not correspond to real zones of effective protection on-the-ground (Liu et al. 2001; see also Bruner et al. 2001). In addition, the condition of biodiversity outside of the protected area is also important because of the impacts that the human-dominated matrix can have on the biodiversity within a protected area (Pereira et al. 2004). Finally, the establishment of protected areas can have negative consequences for human well-being by excluding people from natural resource access (Musters et al. 2000). Nevertheless, 4.2% of the coffee-growing region in Colombia is under protection (over 260,000 hectares), and these ecosystems are in a less disturbed state and are subject to fewer pressures than ecosystems outside of protected areas (Colombia).

Several sub-global assessments applied novel approaches to the assessment of biodiversity. These included composite measures such as the Biodiversity Intactness Index in SAfMA Regional, irreplaceability in the Portugal assessment, conservation status of ecosystems in SAfMA Gariep, the Reef Condition Index in PNG, and the Ecological Integrity Index in Coastal BC.

The Biodiversity Intactness Index provides a useful analysis of biodiversity condition that can be mapped and communicated to user groups. (See Box 8.5.) Irreplaceability, in the Portugal assessment, is a measure of conservation options lost if the site were to be converted or further degraded (Pressey et al. 1993). High irreplaceability values indicate high importance to the conservation targets of a region. The irreplaceability value is not an indicator of biodiversity condition, but can be useful in prioritizing areas for conservation. (See Figure 8.3 in Appendix A.)

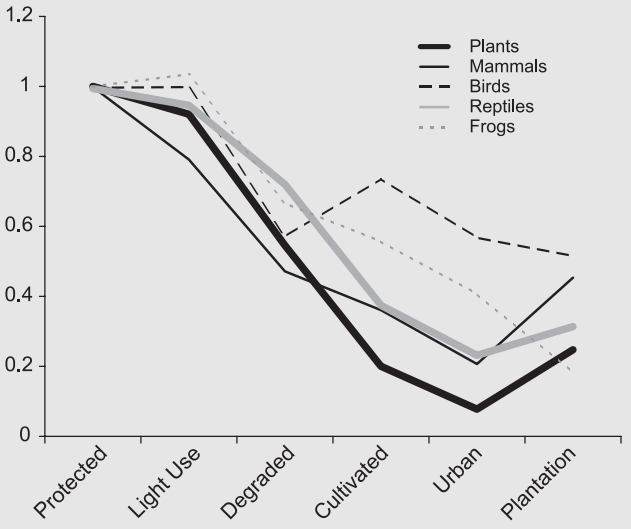
Conservation status analysis of vegetation units provides an indication of the condition of biodiversity at the ecosystem level as measured by land cover change (SAfMA Gariep); here, a gap assessment highlights ecosystems with little protection. (See Box 8.6.) The composite Reef Condition Index is generated by a number of parameters, including coral cover and diversity, as well as fish densities and diversity (PNG). The Ecological Integrity Index is based on measures of ecosystem diversity; species and genetic diversity; soil, water, and air quality; and provisioning and cultural services. (See Box 8.7.) All of these composite indicators were useful in communicating complex information to policy-makers and other stakeholders.

The use of indicators of condition requires a baseline value against which the current value can be compared. SAfMA Regional compared the Biodiversity Intactness Index with levels in protected areas and found that although most of the study area was in good condition, some of the areas and taxa were in poor condition (SAfMA Regional). The Coastal BC assessment applied an innovative approach of comparing their ecosystem dynamics with thresholds of the range of natural variability (Coastal BC); these benchmarks included natural disturbance regimes of canopy gap creation in forests, and flooding events. Setting targets for maintaining the diversity of ecosystems requires the identification of thresholds at which disturbances greater than the natural range would result in detrimental changes.

BOX 8.5

Biodiversity Intactness: SAfMA Regional

SAfMA Regional developed a new index, called the Biodiversity Intactness Index (BII). The BII measures the fraction of the original *populations* of organisms that remain in a given area, integrating across all land uses and all well-described categories of biodiversity. The index has three components: the spatial distribution of land uses of varying intensity; the spatial distribution of species richness per functional type within each main group of organisms and biome; and the impact of land use intensity on each functional type within each biome. These estimates, averaged over biomes and functional types in the graph, are based on three independent assessments by specialists.



Effect of Increasing Land Use Intensity on Fraction of Inferred Original Wildlife Population that Remains.

Some general patterns are evident: non-mobile species such as plants are more adversely affected than mobile species such as birds. Larger organisms and predators are more affected by human activity than are smaller, non-predatory species. Mammals and reptiles tend to track (plant) habitat changes, whereas birds and amphibians show marked non-linearities in their response. The graph shows the BII as applied to South Africa. The results are richness and area weighted averages of BII as estimated at a base resolution of 1 kilometer. Values of BII refer to the average abundance of all species in the particular area, expressed as a fraction of preindustrial era abundance.

8.3.1.3 Condition and Trends

Sub-global assessments reported a variety of conditions for biodiversity, from *excellent* (KM–São Paulo); to *good* (SAfMA, Tropical Forest Margins–Africa, India Local, KM–Eastern Himalayas, and KM–PNG); to *poor* (Tropical Forest Margins–Indonesia and KM–Laguna Lake Basin); to *bad* (Caribbean Sea), with the rest in *fair* condition. Worryingly, the vast majority of sub-global assessments reported a decline in the condition of biodiversity. (See Appendix 8.1.) This suggests that in several places in the globe and across a variety of systems, there is a consistent trend of biodiversity loss. This result is supported by the global analysis of biodiversity trends (MA *Current State and Trends,* Chapter 4) and is of concern because biodiversity is the resource base upon which all ecosystem services are founded (MA 2003). It should be pointed out, however, that the coverage of the sub-global assessments was not uniform across the globe and may have had a bias toward regions undergoing fast ecological change.

Figure 8.4 in Appendix A shows biodiversity condition in the sub-global assessments and the amount of native habitat remaining in each ecoregion of the world (Olson et al. 2001) using data from the MA Scenarios Working Group. This comparison was constrained by the use of arbitrary thresholds for scoring land use change at the ecoregion scale, the use of broad descriptive categories of condition in the sub-global assessments, and the difference between the scales of the sub-global assessments and the scale of the

BOX 8.6

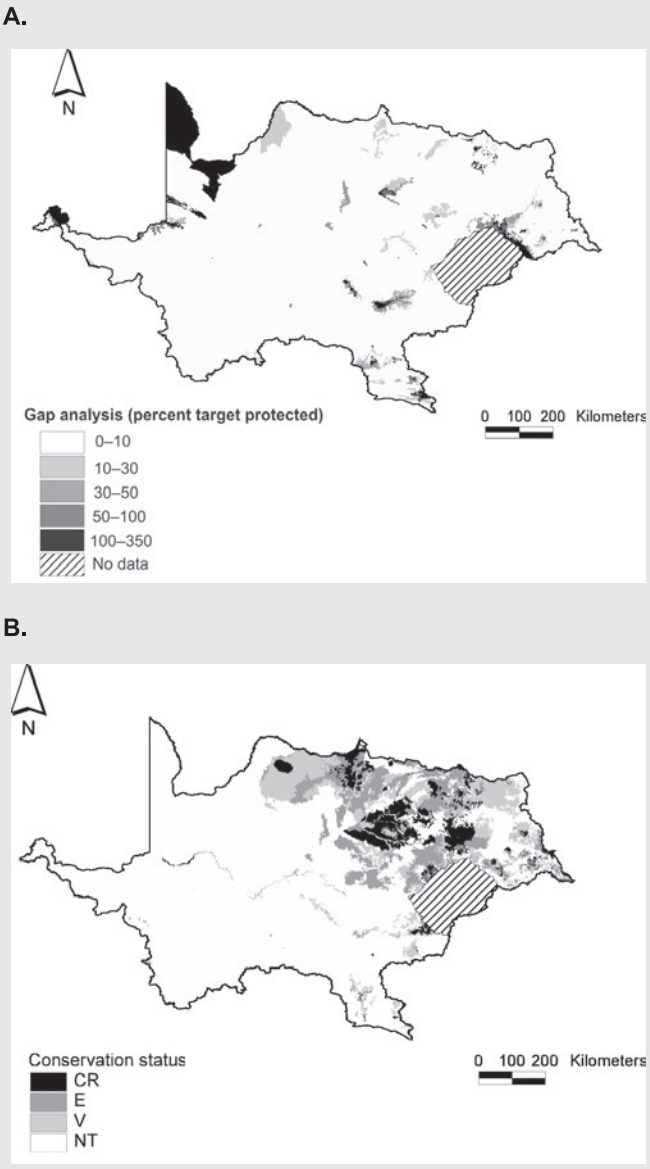
Conservation Targets, Gap Assessments, and Conservation Status: SAfMA Gariep

Conservation targets are an idea gaining strength in the conservation planning literature and represent the extent of occurrences of biodiversity features that a conservation area network should include (Pressey et al. 1993). These targets can be simple and include one occurrence of each species or a cover of, for example, 10% of a vegetation type. However, several techniques now exist to weight targets according to criteria of importance, sensitivity, or rarity. SAfMA Gariep set targets for each of the approximately 2,000 land classes in the Gariep Basin, based on existing methods in Pressey and Taffs (2001) and Reyers (2004). The target for each land use class was defined as a percentage of the original extent and is

$$\text{Conservation Target (\%)} = 10\,(1 + \text{NR} + \text{VU})$$

where NR is the natural rarity of the land class (1—area of the land class relative to the largest land class in the area) and VU is the land class vulnerability to conversion to other forms of land use (from 0 to 1). Based on these targets for each land class, a gap assessment of protected area coverage could be done as well as a conservation status assessment. The gap assessment identifies how well the existing protected areas do in reaching the target for each land class, while the conservation status assessment measures how much of the land class remains in a pristine condition relative to the target area required. The land classes can then be classified in different categories: *Critically endangered* ecosystems are land classes with less area remaining than required by the target, *endangered* ecosystems are those that have lost more than 40% of their original cover, and *vulnerable* are those that have lost more than 20%. These thresholds correspond with the threshold of ecological integrity as proposed by Franklin and Forman (1987).

The figure shows gap assessment (a) and conservation status (b) of land classes in the Gariep Basin (excluding Lesotho, stripes) with (a) representing darker areas that are protected up to and above their target requirements and in lighter colors those that do not yet meet their targets and (b) showing areas that are critically endangered (CR), endangered (E), vulnerable (V), and not threatened (NT)



Gap assessment (a) and conservation status of land classes in Gariep Basin (b) (excluding Lesotho, diagonal stripes).

ecoregions. From this comparison, it seems that there is consistency between the results at the two scales. Exceptions include Norway, which assigned a much lower condition score than found at the ecoregion level; SAfMA G–M, which assigned a much higher score than found at the ecoregion level; and some sites in the Tropical Forest Margins assessment, which showed differences both ways. Note that for sub-global assessments that span several ecoregions, such as Western China, Altai-Sayan, and SAfMA Gariep, the score from the sub-global assessment has to be compared to the average score of the ecoregions.

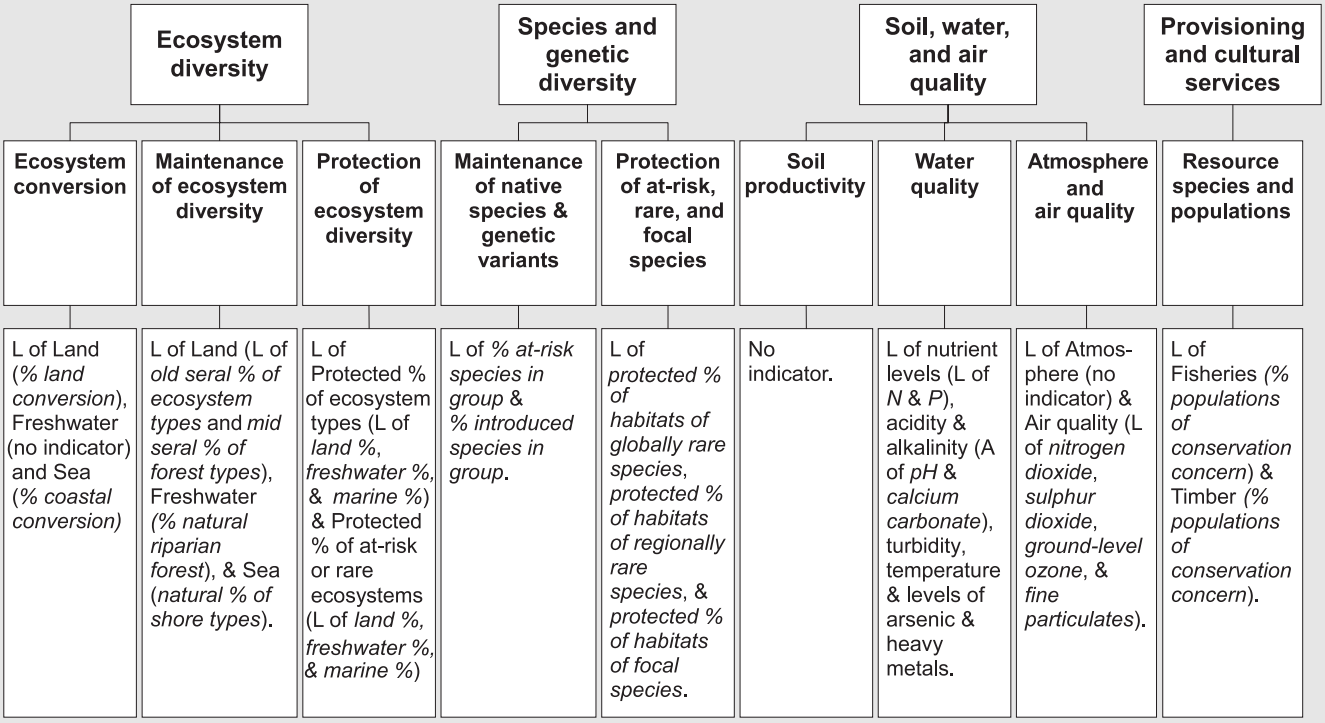
Several sub-global assessments highlighted grasslands as areas of concern due to high impacts of land use and degradation (SAfMA Gariep, Altai-Sayan, Western China). Problems were also reported at the global level, where the Temperate Grasslands biome had lost nearly 70% of its native cover by 1950 and has lost an additional 15.4% since then (MA *Current State and Trends,* Chapter 4).

As highlighted in the section on heterogeneity, the mean condition score in a sub-global assessment does not reflect the complex range of conditions that can be found in the assessment area. For example, the Caribbean Sea assessment found mangrove forests to be in fair condition, and coral reefs in bad condition, but the score assigned to overall biodiversity was ''bad.'' The Norway and Portugal assessments found that the condition of biodiversity in a variety of terrestrial, freshwater, and marine environments varied from bad to fair in Norway and from poor to good in Portugal, with declining trends in most of the ecosystems. Similarly, SAfMA Regional found very different conditions of biodiv-

BOX 8.7

The Ecological Integrity Index: Coastal BC

The Ecological Integrity Index is the unweighted average of scores for four element groups (top line): ecosystem diversity; species and genetic diversity; soil, water, and air quality; and provisioning and cultural services. Element group scores are the unweighted average of element scores (middle line). Element scores are the lowest indicator score, where L = lower/lowest and A = average (bottom line).


Ecosystem diversity
Species and genetic diversity
Soil, water, and air quality
Provisioning and cultural services
Ecosystem conversion
Maintenance of ecosystem diversity
Protection of ecosystem diversity
Maintenance of native species & genetic variants
Protection of at-risk, rare, and focal species
Soil productivity
Water quality
Atmosphere and air quality
Resource species and populations
L of Land (% land conversion), Freshwater (no indicator) and Sea (% coastal conversion)
L of Land (L of old seral % of ecosystem types and mid seral % of forest types), Freshwater (% natural riparian forest), & Sea (natural % of shore types).
L of Protected % of ecosystem types (L of land %, freshwater %, & marine %) & Protected % of at-risk or rare ecosystems (L of land %, freshwater %, & marine %)
L of % at-risk species in group & % introduced species in group.
L of protected % of habitats of globally rare species, protected % of habitats of regionally rare species, & protected % of habitats of focal species.
No indicator.
L of nutrient levels (L of N & P), acidity & alkalinity (A of pH & calcium carbonate), turbidity, temperature & levels of arsenic & heavy metals.
L of Atmosphere (no indicator) & Air quality (L of nitrogen dioxide, sulphur dioxide, ground-level ozone, & fine particulates).
L of Fisheries (% populations of conservation concern) & Timber (% populations of conservation concern).

The following table shows the EII applied to the different sub-regions of North and Central Coastal BC. Sub-regions with no data on air (square brackets) were given a dummy score of 91 (the score of Lower Mid Coast, the lowest of the recorded sub-regions).

Subregion	Ecosystem diversity	Species and genetic diversity	Soil, water, and air quality	Provisioning and cultural services	Ecological integrity index (EII)
Haida Gwaii/QCI	44	40	[91]	27	50
Inner north coast	51	0	[91]	22	41
Outer north coast	63	0	95	23	45
Lower north coast	56	0	93	21	42
Outer central coast	62	0	[91]	17	42
Inner central coast	57	0	[91]	17	41
Upper mid-coast	28	3	93	13	**34**
Lower mid-coast	36	0	91	11	**30**

Bad Poor Fair Good Excellent

ersity in areas under different land use management practices; areas under intensive land use practices like cultivation and plantations have much lower biodiversity condition than those with light intensity uses like grazing.

It is important to note that a lack of data on particular threats and drivers (like land degradation, alien invasives, climate change) could result in an underestimation of threats in a region and thus overestimation of condition. For instance, the SAfMA Gariep Basin reported a poor condition of productive landscapes in the eastern grasslands relative to the arid regions of the west, where biodiversity appears to be relatively intact. However, these arid areas are actually threatened by degradation and desertification, drivers that were not studied or mapped for the region. Thus the actual ecological integrity of the arid regions in the west of the Gariep Basin might not be in as good condition as initially estimated.

Although the condition of biodiversity was generally reported to be in decline, some sub-global assessments had more positive results. For example, the Kristianstad wetlands assessment reported that pre-1989 biodiversity in the region was in decline due to abandoned agricultural land (Sweden KW). The area is largely composed of agro-ecosystems that require active management to be maintained. After 1989, traditional management practices were revived in order to

combat the trend in ecological deterioration. At the same time, awareness of the value of wetlands in the area increased. The process has been gradual, but after an evaluation of new management practices, the assessment concludes that the condition of biodiversity is improving.

Overall these results call for: (1) a clearer definition of biodiversity condition in order to allow for feasible measurements and cross-assessment comparisons; and (2) the development of biodiversity monitoring programs that use standard biodiversity measurements over time.

8.3.2 Supporting Services

Supporting services are those that are necessary for the production of all other ecosystem services (MA 2003). The supporting services assessed by sub-global assessments include primary production (Western China, Laguna Lake Basin, SAfMA), soil formation (Portugal, Tropical Forest Margins, Norway), nutrient cycling (Tropical Forest Margins), and habitat provisioning (Altai-Sayan). The distinction between a supporting service and a regulating service was in many cases uncertain. For instance, the Portugal assessment analyzed soil protection as a regulating service, but this analysis also included an assessment of the soil condition in terms of nutrient supply, accumulation of salts from irrigation, and pollution from point sources. All of these components were part of an assessment of the soil as a resource base on which other services depend, which is a supporting service. Similarly, primary production is closely related to the regulating service of carbon sequestration (Portugal), and the habitat provisioning service is often an integral component of a biodiversity assessment.

8.3.2.1 Drivers

The primary productivity of an ecosystem is mainly driven by climate and the supply of water and nutrients from the soil (Brown and Lomolino 1998). Human-induced drivers of primary production include eutrophication of water bodies (Laguna Lake Basin), land use change (Western China), and climate change (Western China).

The physical, chemical, and biological properties of soils determine their overall supporting service and are affected directly by the following drivers:

- land use change, including deforestation (Tropical Forest Margins, Norway), afforestation (Portugal), and road construction (Tropical Forest Margins, Norway);
- external inputs such as irrigation, fertilizers, and pesticides (Norway, Portugal, Western China);
- pollution from mining (Portugal);
- agricultural practices such as tilling and crop rotation (Argentine Pampas, Portugal, Norway); and
- fire frequency (Portugal, Altai-Sayan).

In some regions, an important human-induced driver of the nutrient cycling service is the depletion of nutrient stocks through the repeated harvesting and removal of produce without replenishment of those nutrients (Tropical Forest Margins, SAfMA Regional). Finally, habitat provisioning is affected by much the same drivers as biodiversity at the ecosystem level. Sometimes the impacts of a driver can be reversed through restoration measures (Western China). As an example, trees can be planted on cultivated land to accelerate ecological succession from crops and grassland to forest.

8.3.2.2 Indicators

In the Western China assessment, changes in net primary productivity (NPP) were estimated using ecosystem models and land cover maps. (See Box 8.8.) In SAfMA, the difference between grazing pressure and potential capacity (based on NPP) was used as a measure of rangeland degradation, that is, desertification (SAfMA Regional). Desertification can be caused by overgrazing or by a decrease in soil organic matter and leads to a decrease in vegetation cover and primary productivity.

Indicators of soil condition include concentration of salts, depth of soil layer, soil compaction, nutrient loading, and organic matter content (Portugal, Tropical Forest Margins). In order to assess the nutrient cycling service, the Tropical Forest Margins assessment used two indicators: net nutrient export and relative net nutrient replacement cost. Net nutrient export is the nutrient input minus nutrients harvested. Relative nutrient replacement cost equals the cost of putting the exported nutrients of harvested products back into the agroecosystem in the form of chemical fertilizer. Nutrient inputs were assessed primarily through interviews with farmers at the sites but also using national or district level statistics (for mineral fertilizer use, if available). Nutrient contents of organic inputs were obtained from the literature. Nutrients removed through harvesting were determined by the crop or tree product yield (obtained from field interviews and agricultural statistics) and multiplied by the concentration of nutrients in the different products (Stoorvogel and Smaling 1990). The nutrient balance was determined as the difference between inputs and outputs for nitrogen, phosphorus, and potassium. The cost of nutrients in the form of mineral fertilizers and price of crops was obtained from local markets and statistics.

8.3.2.3 Condition and Trends

By analyzing photosynthetic–thermal farmland productivity, the Western China assessment found that from the

BOX 8.8

Supporting Ecosystem Services: China

The Western China assessment monitored land use/cover change in China using remote sensing data, such as satellite images and other data sources, integrated in a GIS system. It was found that between 1990 and 2000, the area of cropland, towns, rural residences, and water bodies increased across western China, while the area of woodland and grassland decreased. By using ecosystem models, the changes in the condition of primary production due to land use changes in China were estimated (Liu et al. 2003). Net primary production has increased over most of China, but has decreased in the Loess Plateau and the western part of the northeastern China. At the same time, food production has also increased in China. (See the Figure for this box in Appendix A.)

1980s to the 1990s, due to climate change, productivity increased by 44 million tons. During the 1990s, due to land use and land cover change, photosynthetic–thermal farmland productivity increased by 22 million tons. In contrast, the Laguna Lake Basin assessment reports a serious problem with the primary production service in a freshwater system. The biological productivity of Laguna de Bay has declined considerably, especially during the last 30 years. Assessment of the levels and trends of primary productivity of the lake during the period 1990–2000 shows erratic behavior, with NPP levels generally below 1 gram of carbon/m^2/day. This is about 20% of the NPP observed in the 1970s. The main reason is the very high water turbidity that limits light penetration and photosynthesis; fish harvests have declined commensurately.

Several sub-global assessments reported a poor condition of soil-related supporting services (Norway, KM–Western China, KM–Eastern Himalayas, KM–Downstream Mekong, Tropical Forest Margins; see Appendix 8.1). This is of great concern because the recovery of degraded soil can be a slow process (Portugal). Soil erosion was identified as a major problem affecting the condition of supporting services in many assessments. In SAfMA Regional, about half of the subhumid and semiarid parts of the region are at moderate to high risk of desertification due to grazing pressure. Overgrazing has reduced yields by a third in Western China and is also a serious problem in the grasslands of the Altai-Sayan ecoregion. In Norway, Portugal, Western China, and Eastern Himalayas, bad agricultural practices and the cultivation of marginal lands have caused erosion of the topsoil in some areas. In China, the government has recently implemented a regulation that calls for existing cultivated land with slopes of more than 25 degrees to be restored gradually to forest and grassland, or changed into terraced land. (See also Portugal for a case study of terrace agriculture.) Problems of salt accumulation in the soil caused by irrigation were reported in the drylands of Western China and Portugal. The Norway assessment reported that intensive extraction of biomass contributes to increased acidification of the soil, with consequent chemical effects on run-off water. Downstream Mekong reported a decrease in the alum-washing process by seasonal inundation and floods because of increased drainage systems, leading to impacts of alum on agriculture.

8.3.3 Provisioning Services

Provisioning services are the products obtained from ecosystems (MA 2003), also known as ecosystem goods (Daily 1997). The provisioning services assessed by the sub-global assessments included: fresh water, food, fuelwood, fiber, and to a lesser extent, biochemicals. Among these, freshwater provisioning was the service most commonly assessed.

8.3.3.1 Drivers

Drivers affecting provisioning services are varied and are explicitly linked to indirect drivers. *Indirect drivers* include population growth, lifestyles, diet, governance, regulations, and markets. *Direct drivers* include:

- land use change;
- external inputs, including irrigation, fertilizer use, pesticide use, and pollution;
- technology adaptation, including aquaculture and agricultural intensification;
- introduction of species and agricultural varieties, including tree species and fish species for aquaculture;
- harvest (deforestation, overfishing); and
- climate change and yearly weather fluctuations.

The links between each indirect driver and changes in provisioning services are often explicit. For instance, the decrease in household size (an indirect driver) directly affects the patterns of fuelwood consumption in the Eastern Himalayas.

Direct drivers can affect several provisioning services. For example, a direct driver of food provisioning such as irrigation may affect water quality indirectly through the accumulation of fertilizers and salts in groundwater (examples include Portugal and Sinai). Another example is deforestation that directly affects food provisioning (by increasing available area for agriculture, as in Tropical Forest Margins) but at the same time can also affect other provisioning services such as water (Northern Range) and fuelwood (SAfMA). But the specific drivers in each of the broad categories mentioned above may also differ across provisioning services. For instance, ''technology adaptation'' drivers of food provisioning include agricultural intensification (examples include Norway, Portugal, PNG, Downstream Mekong) and aquaculture production (Laguna Lake Basin), while ''technology adaptation'' of drivers for water provisioning includes water extraction techniques (PNG) and water use efficiency (SAfMA), and for fuelwood provisioning, it corresponds to alternative energy sources (SAfMA). Similarly the main land use driver affecting food provisioning is the change in area for various crops (San Pedro de Atacama, India Local, Laguna Lake Basin, Portugal, Downstream Mekong), while the land use driver affecting water provisioning includes dam construction and inter-basin water transfers (SAfMA, Portugal).

8.3.3.2 Indicators

Indicators for the condition of provisioning services are more readily available than for other ecosystem services. Therefore, it is not surprising that all the sub-global assessments assessed at least one provisioning service (Appendix 8.1). There are national statistics on food production (FAO 2001), timber production (FAO 2003), water production, and water quality. However, these data were not always available at the scales of the assessments; in some instances, sub-global assessments had to collect their own data (for example, Tropical Forest Margins and Laguna Lake Basin).

Sub-global assessments used a range of indicators to assess the condition of the water provisioning service, measuring different aspects of the service. Measures of water quality, including physical, chemical, and biological parameters can be used to assess the suitability of water for human consumption or irrigation (for example, Laguna Lake Basin, Altai-Sayan, Portugal). Water quality is affected by several point pollution sources, but also by drivers such as soil ero-

sion and dam construction. It is also important to measure the quantity of water available. This can be assessed by simple measures such as lake depth (for example, Laguna Lake Basin and Western China) or more elaborate measures such as a supply–demand analysis (for example, SAfMA Regional, Downstream Mekong, São Paulo). Finally, issues of equity in access to water resources can also be considered (for example, Sinai, SAfMA Gariep).

Similarly, several indicators were used to assess the condition of food provisioning. Indicators of the amount of food produced included agriculture production (for example, San Pedro de Atacama, Downstream Mekong, Sinai, Portugal, Laguna Lake Basin), fish landings (for example, Caribbean Sea, Downstream Mekong), and area under cultivation (for example, Sinai). Because food is less of a local service than water provisioning, supply–demand analysis played a more limited role in the assessment of this service (but see SAfMA). SAfMA also undertook an analysis of food access, equity, and food security.

The supply or production of a service may tell little about the capacity of the system to continue to provide that service. The Portugal assessment looked at indicators of the capacity of ecosystems to provide food, such as the level of fertilizer and pesticide use, soil erosion, aquaculture practices and the condition of fish stocks (measured by the number of species above the precautionary biomass threshold).

Some assessments analyzed the production of fiber and fuelwood. Indicators of production volume (SAfMA, Portugal) and production economic value (Portugal) of fiber were used, as well as indicators of standing stock (Tropical Forest Margins, São Paulo). A supply–demand analysis, comparing rate of wood felling with the rate of wood growth, was performed at the national level by Portugal and at the local level by SAfMA. Other indicators of sustainability included the type of management system and management practices (São Paulo, Portugal). India Local analyzed the history of local forests, including logging, invasion by alien species, and fire frequency.

Few assessments analyzed the provisioning of biochemicals by ecosystems. For instance, the Downstream Mekong assessment surveyed bioactive substances (such as color products) produced by plants, while the Sinai assessment analyzed the condition of the populations of medicinal plants.

8.3.3.3 Condition and Trends

Serious problems with the water provisioning service were found in four sub-global assessments. In San Pedro de Atacama in Chile, water is a scarce resource and high levels of arsenic occur naturally in the water; there is much uncertainty, conflict, and misinformation regarding water availability, with total requests for irrigation, mining, and potable water exceeding available volumes (San Pedro de Atacama). In the Laguna Lake Basin, the quality of the water in the lake and tributary rivers is poor, with total coliform counts exceeding the class ''C'' maximum standards (suitable for fisheries, according to the Water Quality Criteria of the Philippine Department of Environment and Natural Resources). Other problems include very low levels of dissolved oxygen, an NPP rate characteristic of a hypereutrophic lake, and the presence of toxic and hazardous substances such as mercury, cadmium, chromium, copper, and lead. Major sources of pollution entering the river systems of Laguna de Bay are domestic wastes (the largest source), food processing plant wastes, livestock wastes, chemical manufacturing spillage, various industrial effluents, fertilizers and pesticides from agricultural runoff, and eroded soils from the watersheds (Laguna Lake Basin). In the Gariep Basin, average per capita runoff is 1,096 cubic meters per year, nearly placing it in the ''chronic scarcity'' category (Falkenmark and Widstrand 1992). Ecological reserve requirements—16% of the basin's total annual runoff set aside to ensure proper ecological functioning—are not met in 43% of the Gariep's catchments. Furthermore, as of 1998, 12 million South Africans did not have access to an adequate supply of potable water (King and Louw 1998). One of the problems was that riparian property rights favored owners with water on their land, but there is now a government strategy aimed at more equitable distribution of water (SAfMA Gariep). In Northwestern China, water is a scarce resource. With economic development and population growth in the region, the decreasing allocation of water to the ecological reserve has caused ecosystem deterioration. The continuous expansion of artificial oases and widespread irrigation has not only wasted the limited water resources but has also caused land salinization (Western China).

Figure 8.5 in Appendix A compares the world distribution of population relative to a water scarcity threshold, defined as the ratio of water withdrawal or water use to discharge (MA *Current State and Trends,* Chapter 7), with the qualitative assessments of water provisioning from selected sub-global assessments. Agreement is good overall, with sub-global assessments reporting a poor to bad condition of water provisioning in regions where water demand is above the threshold (KM–SAfMA Gariep, San Pedro de Atacama, KM–India Urban, KM–Western China—for northern parts, and KM–Laguna Lake Basin), and a good to excellent condition in areas where water demand is below the threshold (KM–Bajo Chirripó, Tropical Forest Margins, KM–SAfMA GM, Norway, KM–Western China—for southern parts, and Altai-Sayan). The analysis of the assessments that reported a fair condition of water provisioning was more difficult, because they covered very heterogeneous areas (examples include Portugal and KM–Sinai). At least one clear disagreement occurred with Trinidad's Northern Range; the global assessment suggests that the island is above the water scarcity threshold, but the local assessment identified a trend of decreasing water quality and quantity due to watershed degradation (for example, deforestation), projecting that by 2025 there will be a shortage of water (Northern Range). This led the assessment team to report a fair value for the water provisioning service.

Three sub-global assessments reported serious problems with food provisioning services (Appendix 8.1). In Southern Africa, there has been a downward trend in per capita protein consumption over the last 25 years, and total protein intake averaged over the entire region is 8% below the recommended WHO minimum for adequate nutrition,

with some areas such as the Democratic Republic of Congo and Mozambique much below this minimum (SAfMA Regional). Protein hunger contributes to negative impacts on wild mammal and bird populations, through the ''bushmeat'' trade. There is little scope for increased off-take from natural fisheries, half of which are already overfished. However, there is a technical opportunity for greater protein off-take from livestock. The situation for carbohydrate crops is less serious, with the region on the whole producing enough to meet minimum needs even though up to 15% of the population is undernourished due to distribution inequities (SAfMA; Bob Scholes, personal communication). In the Caribbean Sea, fish catches peaked in the mid to late 1990s but have since declined by 30%, probably due to overfishing. (See Figure 8.6 in Appendix A.) The increased harvest in the mid 1990s was due to an increase in the catch of small herring-like fish, while the late 1960s peak was associated with the harvest of piscivorous perch-like fish. This suggests the possibility of a ''fishing down the food web'' pattern (Caribbean Sea). Finally, the Laguna Lake shoreland supplies 14% of the total rice requirement in the Laguna Lake region. However, this production is affected by a multitude of factors, such as the decrease in water level, quality of rice culture, and land conversion. Furthermore, the fisheries of Laguna Lake have been affected by human, industrial, and environmental factors that resulted in significant decline in both production and species diversity.

At the other extreme, some sub-global assessments considered the food provisioning service to be in good condition. For instance, the Tropical Forest Margins assessment focused on the edges of forests, where food production is higher relative to the baseline used in that assessment—food production inside the forest. In Portugal, despite food production in the cultivated systems having grown at a much slower rate than national food demand, this was not considered a critical problem by local experts. Instead, attention was focused on the sustainability of agricultural practices and fish harvesting. Use of fertilizers and pesticides is generally low, when compared with other EU countries, but there is excessive fertilizer use in some places. Other problems include soil erosion and loss of fertile soil to urban sprawl. Oceanic fish stocks have improved over the last decade but coastal fisheries are doing worse, partially because of pollution and eutrophication (Portugal).

About half the sub-global assessments assessed timber and fuelwood provisioning (Appendix 8.1). The only critical case occurred in Tropical Forest Margins-Indonesia, where the assessment team reported a bad condition for the service. In Portugal, two types of wood provisioning were distinguished: timber from plantation forests and cork from the cork-oak woodland (*montado*). Portugal produces more than 50% of the world cork supply. The ecological sustainability of cork production is high, and cork production has been practiced in a way that has helped to protect the southern woodlands over the last several decades. As a consequence, the *montado* is faring well for a range of services. In contrast, some practices of the forest industry, including the planting of eucalyptus in inappropriate soils, and excessive fertilizer use, garnered only a fair score from the Portugal assessment team.

Only a few assessments analyzed the provisioning of biochemical substances (examples include Downstream Mekong and Sinai). The Downstream Mekong assessment compiled an inventory of the species providing different types of substances. The assessment identified 16 plant species providing toxic products, 28 species providing color products, and 21 species providing tannins. In addition, it was found that other biochemicals could be extracted from snake venom, scorpions, and honeybees.

8.3.4 Regulating Services

Regulating services are the benefits obtained from the regulation of ecosystem processes (MA 2003). Regulating services assessed by sub-global assessments included:

- runoff regulation, flood protection and soil protection,
- regulation of water quality,
- regulation of air quality,
- climate regulation (local regulation through albedo, and global regulation through carbon sequestration), and
- disease regulation.

8.3.4.1 Drivers

Drivers affecting the condition of regulating services in the sub-global assessments include:

- climate change,
- land use and topographical changes,
- invasion of alien species,
- loss of important species,
- human population growth,
- government and policy changes, and
- technological developments.

For example, alteration of precipitation induced by climate change has the potential to affect the spatial runoff pattern and the ability of ecosystems to regulate flooding. Land use change can substantially alter ecosystem type and result in tremendous effects on the regulating services of ecosystems (Laguna Lake Basin, Western China, SAfMA Gariep). The Western China assessment reported that the transformation of forest to cultivated land resulted in the upstream portion of China's Yangtze River becoming a fragile ecosystem. This caused an increasingly serious soil erosion problem and decreased the ability of the soil to conserve water during heavy rain events, resulting in more frequent flooding problems in the Yangtze catchment.

Indirect drivers such as policy change and population growth alter anthropogenic pressures on ecosystems and their ability to regulate the environment. Changes in government policies were recognized most widely as important drivers influencing the services (including regulating services) of ecosystems in many sub-global assessments, including Western China, SAfMA, Laguna Lake Basin, India Local, São Paulo, PNG, Downstream Mekong, and Altai-Sayan.

8.3.4.2 Indicators

The Coastal BC assessment did not attempt to determine the condition of regulating and supporting services but in-

stead focused on the ecosystem conditions required for those services. This approach was taken by other sub-global assessments as well; for example, the Caribbean Sea assessment used indicators of biodiversity condition (mangrove extent) as proxies for the condition of regulating services.

A soil erosion map can show where an ecosystem has lost the capacity to conserve its soil layer and where the ecosystem still conserves that capacity. In the São Paulo assessment, areas with exposed soil, high landslide frequency, and high rates of sediment transfer were used as an an indicator of soil stability and runoff regulation. Land use is an important driver affecting the regulating services of an ecosystem, and a map of land cover change can serve as an indicator of changes in the condition of regulating services such as climate regulation (Laguna Lake Basin).

Water quality was assessed by many sub-global assessments. In some cases, water quality was assessed as part of the provisioning service of fresh water; in others, it was evaluated as an indicator of the condition of water quality regulation services. Laguna Lake Basin, SAfMA, Coastal BC, San Pedro de Atacama, Caribbean Sea, Portugal, Sinai, India Urban, and Northern Range all assessed water quality using indicators of levels of pollutants and other physical measures (for example, nitrates, phosphates, heavy metals, pH, calcium carbonate, harmful bacteria). Air quality was also assessed using levels of pollutants (nitrogen and sulfur dioxide, ozone, fine particulates) in Coastal BC and SAfMA Gariep.

In some assessments, the condition of forest ecosystems was used as an indicator of regulating services. Forests (especially those upstream of an important water resource) are an important component of water resource protection. They play an important role in the regulation of runoff, increasing the flow during the dry season and minimizing flooding during the wet season. Forests also prevent soil erosion. The forest canopy intercepts the rainfall thus reducing its kinetic energy and promoting water infiltration in the soil (Portugal). The tree roots protect the soil, minimizing the accumulation of sediments in reservoirs and rivers, therefore improving water quality. (See Box 8.9.) Forests also maintain the air quality by absorbing carbon dioxide, air particles and pollutant gases, and by producing oxygen. However, in some instances, plantation forests of alien species can be a serious threat to regulating services through the alteration of runoff and hydrological regimes (SAfMA Gariep).

8.3.4.3 Condition and Trends

Most sub-global assessments report a fair to poor condition of regulating services in their ecosystems (Appendix 8.1). The exceptions include Coastal BC, where air and water quality are in good condition as would be expected in an area with a low human population density and low levels of industry. In most cases, regulating services are either stable or declining in condition. The Laguna Lake Basin assessment of climate regulation found that the loss of forest has implications for the amount of carbon that can be sequestered; reforestation of these degraded lands has the potential to sequester more than 1,338 kilotons of carbon dioxide per year, which is enough to turn the basin into a net carbon sink (Laguna Lake Basin).

8.3.5 Cultural Services

The MA conceptual framework defines cultural services as the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, and recreation (MA 2003). These benefits include cultural diversity, a sense of place, tourism, educational values, and aesthetic values. As is obvious from this definition, cultural services are complex (see Chapter 11) and perceptions of these services vary across individuals and communities. Recognizing and evaluating the condition of cultural services is relatively new and the MA aimed to explore new ways of evaluating these services and their condition.

The sub-global assessments evaluated a few of the wide range of cultural services. Most assessments—including Caribbean Sea, Laguna Lake Basin, Portugal, Downstream Mekong, SAfMA Regional, and São Paulo—focused on tourism as a cultural service. India Local assessed spiritual services through expert workshops; SAfMA Livelihoods and Sweden KW assessed spiritual and aesthetic services; Sweden SU assessed recreational and educational services. Trinidad assessed a wide variety of cultural services including recreation, eco- and agrotourism, cuisine, and religious and spiritual values. Coastal BC found that in rural societies provisioning and cultural services are often viewed as being identical. Thus the assessment grouped services into economic services (provisioning services that provide direct monetary benefits) and cultural services (provisioning services that provide material and nonmaterial benefits including the provision of food, raw materials for art, and sites of spiritual value).

8.3.5.1 Drivers

Tourism and recreational use (for example, driving on beaches) were identified as drivers of change in the condition of sensitive ecosystems. Tourism is one of the fastest growing industries in the world (WTTC 2004). Nature-based tourism, that is, tourism motivated by a desire to visit places of natural beauty, is a particular area of growth. This form of tourism includes many activities from fishing to lazing on a beach and relies on the presence of attractive biodiversity, unspoiled scenery, and other ecosystem services that provide clean water and air. Most of the sub-global assessments that assessed tourism were in actual fact assessing nature-based tourism. Many claimed to be assessing ecotourism, which is defined as nature-based tourism that is environmentally and culturally sensitive while being sustainable.

Other drivers of change in ecosystem condition—for example, pollution and land cover change—were also identified as drivers of change in the cultural services of ecosystems. The Laguna Lake Basin found that water pollution is affecting the Lake's tourism potential negatively.

8.3.5.2 Indicators

Some cultural services can be directly linked to a harvesting activity such as recreational fishing or hunting (MA 2003).

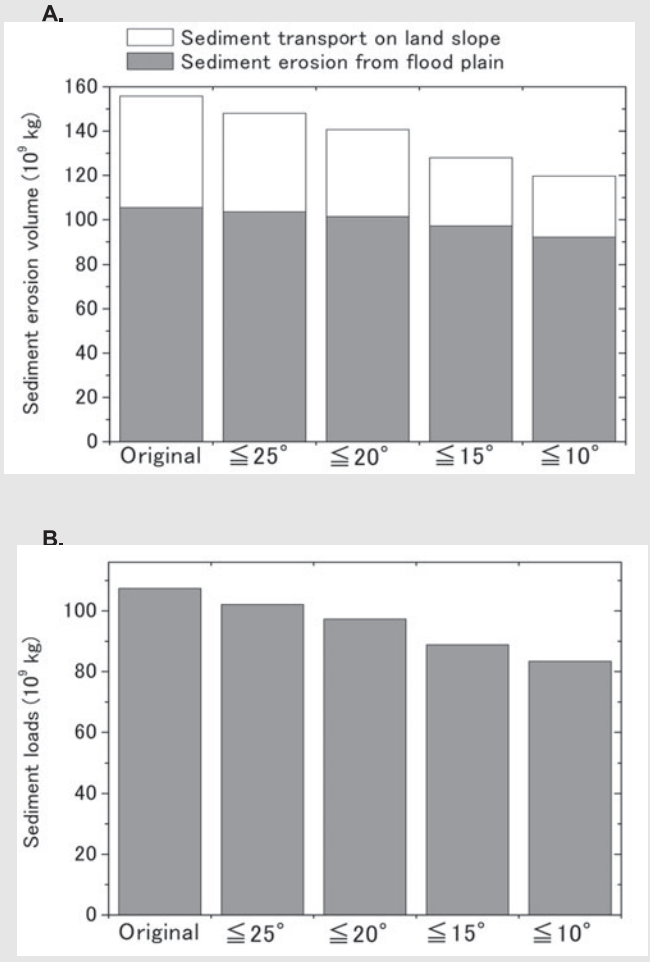
BOX 8.9

Controlling Floods and Decreasing Sediment: Western China

The Western China assessment studied the effect of land use change on sediment loads in the Jialingjiang River catchment (160,000 square kilometers), which is a tributary of the Changjiang (Yangtze) River, using a hydrologic model (Hayashi et al. 2004). The validation of the model was based on the observed daily flow rates and sediment loads of 1987. The effect of converting farmland to forest in steep slopes was examined with scenarios. Afforestation is one of the main policies of the Chinese government for flood protection, and aims to mitigate the flood peak and decrease sediment loads.

Afforestation in areas in four grade classes were considered: >25°, >20°, >15°, and >10°. Farmlands with a slope value greater than 25°, 20°, 15°, and 10° cover 0.6%, 1.5%, 3.2%, and 6.3% of the Jialingjiang catchment, respectively. Also, these corresponded to 1.6%, 3.8%, 8.2%, and 16% of the total area of farmlands in the catchment, respectively. No differences were found for runoff between the different slope classes. However, volume of sediment erosion decreased with afforestation, particularly for the scenarios where more area was afforested, showing afforestation to be effective for the protection of sediment production. The simulated annual total sediment loads from the whole catchment decreased up to 22% in the scenario with largest afforestation (slopes > 10°).

Figure A shows annual total sediment erosion volume including sediment transport on land slope and sediment erosion from floodplain, for the different scenarios. Figure B shows annual total sediment loads from the whole Jialingjiang River catchment for the different scenarios.



Other cultural services can be linked to particular ecosystem features that are of cultural, aesthetic, or spiritual value (for example sacred pools). (See Box 8.10.) These features can then be assessed and trends in their condition used to infer condition of the cultural services. However, many cultural services do not link to particular features or provisioning services and thus require new techniques for their assessment.

The large number of sub-global assessments investigating tourism is perhaps understandable as it is one of the easier cultural services to quantify. In fact, some sub-global assessments assessed the economic value of nature-based tourism (for example, SAfMA Regional). (See Table 8.4.) Other assessments analyzed visitor numbers (Colombia) or ecotourism potential (Laguna Lake Basin, Downstream Mekong). These indicators were used to assess the condition of tourism as a cultural service of the ecosystems in question. Sub-global assessments also viewed tourism as a tool for development and an important source of economic growth, with stakeholders often requesting its inclusion in the sub-global assessments.

Although tourism was assessed across sub-global assessments at most spatial scales, spiritual, religious, recreational, and educational services tended to be assessed only in small local-scale studies (for example, India local and SAfMA Livelihoods)—perhaps because the data required for these assessments are not available at coarse scales. In conducting such fine-scale analysis, local assessments relied on community workshops to garner information.

In general, except for tourism, the assessment of cultural services relied on descriptive information rather than quantitative data, generated mostly through participatory approaches. These assessments sometimes only provided a description of the service and not necessarily an assessment of the condition of the service.

8.3.5.3 Condition and Trends

It would appear from the sub-global assessments that tourism and recreation are in a fair to good condition with improving trends (Appendix 8.1), with no sub-global assessment reporting a poor condition. Yet within these findings, there is considerable heterogeneity. For example, SAfMA Regional found that tourism is high and growing in some regions but low in others. In its attempts to explain the large amount of variation in the condition of tourism in southern Africa, SAfMA Regional paid a lot of attention to the condition of nature-based tourism. The factors responsible for the importance of tourism include the quality and extent of natural assets, ease of access to these assets, and perceptions

BOX 8.10

The Cultural Importance of Ecosystem Services: SAfMA Gariep

In the Great Fish River area, local Xhosa people of the Eastern Cape, South Africa, place great cultural and utilitarian value on key resource patches such as mountains, forests in various stages of succession, and a variety of grazing lands. In many cases, the diversity of resource patches is the consequence of people interacting with the land, where these patches are created through a variety of induced disturbances. The different types of resource patches provide different kinds of resources, thus satisfying the villagers' basic needs. These include both practical, physical needs and cultural and spiritual needs.

Rituals and traditions are central to the culture and identity of the Xhosa people. Key resource areas are fundamental to the performance of these rituals and include sacred pools, dense forests, and mountains. Each of these sites has particular rituals associated with them, with specific benefits. The most important of these sites are sacred pools. In the assessment area, these are typically places of still deep water, with water flowing above and below; they often have steep banks and are surrounded by particular species of trees and plants such as *Salix capensis,* which is regarded as the tree of the "river people," *Cyperus textilus,* and a variety of small plants and creepers such as *Tecomaria capensis.* The plants indicate the presence of the ancestors and the river people: mermaid-like creatures associated with the generation of water, rain, healing, and fertility of the land.

The sacred pools provide people a place of direct communication with the spirit world where they can access blessing and health and also give thanks and veneration through the performance of particular traditions. The sites are critical points in the landscape where culture in the form of traditions and connection with the ancestors is maintained.

Sacred pools also have a practical benefit, in that they are important water sources during times of severe drought. The reason they do not dry up is related to the many taboos associated with sacred pools where, for example, one is not allowed to harvest medicinal and other useful plants unless one is a diviner or *igqirha.* The vegetation surrounding sacred pools is therefore denser and provides a protective canopy, thus reducing the effect of evaporation.

Table 8.4. Nature Tourism Numbers and Revenue: SAfMA Regional, 2000

	Nature Tourism Arrivals (thousands)			Income from Nature Tourism ($ millions)			
	Non-African	African	Domestic	Non-African	African	Domestic	Total
Angola	0.8	0.1	..	0.3	0.0	..	0.3
Botswana	110.4	362.5	..	30.6	100.6	..	131.3
Burundi	0.0	0.0	..	0.0	0.0	..	0.0
Congo	0.0	0.0	..	0.0	0.0	..	0.0
Dem. Rep. Congo	0.0	0.0	..	0.0	0.0	..	0.0
Equatorial Guinea	0.0	0.0	..	0.0	0.0	..	0.0
Gabon	28.0	0.0	..	1.3	0.0	..	1.3
Kenya	552.8	201.6	0.2	178.2	65.0	7.5	250.7
Lesotho	5.4	48.4	..	0.6	4.9	..	5.5
Malawi	18.4	91.0	..	2.2	10.8	..	13.0
Mozambique	6.0	36.0	..	1.2	7.2	..	8.4
Namibia	96.6	263.4	..	45.3	202.3	..	247.6
Rwanda	1.7	0.0	..	2.7	0.0	..	2.7
South Africa	1,203.3	3,425.6	5.6	504.4	1,436.0	358.4	2,298.8
Swaziland	77.3	166.6	..	15.9	11.0	..	27.0
Tanzania	203.7	0.0	..	299.9	0.0	..	299.9
Uganda	28.0	92.8	..	27.6	91.6	..	119.2
Zambia	137.6	321.6	..	21.85	1.0	..	72.8
Zimbabwe	358.4	1,136.0	..	34.4	109.1	..	143.5
TOTAL	**2,828.4**	**6,145.6**		**1,166.4**	**2,089.5**		**3,622.0**

by visitors of risks to personal safety and health. Natural assets can refer to a particular site or a landscape as a whole. SAfMA Regional evaluated the relationship between biodiversity and tourism, but found the relationship to be indirect and often not immediate. For the majority of visitors, a few particular elements of biodiversity (for example, the "Big Five": lion, elephant, rhinoceros, buffalo, and leopard) are the attraction. Other tourists are more interested in the variety of life itself (for example, botanists and birdwatchers). Whatever the attraction, tourists appear to distinguish natural and artificial experiences (resource reserve versus zoo) and prefer the former, which explains the attraction of many sites in southern Africa. SAfMA Regional assessed the limits to nature-based tourism and suggests that the carrying capacity of wilderness areas for this service is roughly one visitor per square kilometer.

Although most sub-global assessments found tourism to be in good and improving condition, some found declines. Portugal, for example, reported a declining trend in the condition of recreation in cultivated and coastal systems. This was caused not by a decrease in the demand for recreation services, but instead by a decrease in the capacity of those ecosystems to support recreation. The coast in Portugal is showing some signs of saturation, and the cultivated system is becoming either intensively farmed or abandoned, which is less attractive for tourism than traditional agricul-

ture systems. The San Pedro de Atacama assessment reported a decline in mass tourism counterbalanced by increasing special-interest tourism. Some sub-global assessments expressed concerns that tourist activities are causing declines in the capacity of ecosystems to provide this cultural service (SAfMA Regional, Caribbean Sea).

In general, the improvement in the condition of tourism and recreational services, measured mostly through tourist numbers, economic value, or qualitative potential, seems to indicate positive future trends for these services, if managed appropriately. This is not surprising, considering that the demand for these services is increasing. SAfMA Regional found that tourists in the study area enjoy significant ''consumer surplus,'' with tourists willing to pay more than they actually do. This has led to growth in privately owned conservation land, private concessions on state-owned land, and a two-tiered payment system.

Assessment of non-recreational cultural services such as religious and spiritual services produced different results; assessment reports on the condition of these services are descriptive and generally indicate a fair but declining condition. India Local highlights the impacts of overuse of some sites; India Urban reports a decline based on loss of wilderness areas and declines in cultural value of sites; and Downstream Mekong reports decreases in condition due to a loss of inspirational values. In a similar vein, SAfMA Livelihoods blames land use pressures that have threatened sites of cultural importance and that—together with increasing urban contact, modernization, and influences of other cultures—have made inroads into cultural beliefs and norms. According to the older generation, a decline in cultural identity and respect from youths explains the deterioration of the landscape due to the anger and disappointment of the ancestors. This links well with the findings of the MA's global assessment of cultural services, which identified the following causes of the decline in traditional value systems: rapid urbanization, the break down of traditional families in rural areas leading to the increase in nuclear families, economic development–related market forces, replacement of traditional institutions with modern ones, and resulting inter-institutional conflicts. The global assessment also found that these forces are countered by changing global attitudes toward recognizing the links between natural and cultural heritage values.

In the past in Costa Rica, spiritual values and beliefs associated with local ecosystems protected ecosystem services (Bajo Chirripó). The indigenous people of the Cabécar territory believed in the existence of spiritual entities, guardians of the ecosystems that controlled natural resources. Access to sacred woods was limited, which maintained biological diversity. Unfortunately, these spiritual values have been eroded, and part of the assessment effort has been directed at finding mechanisms to rebuild these values. The Quechua people of the Peruvian Andes believe in mountains as living beings, owners of the vital energy that controls all the animals and plants (Vilcanota). The well-being of the community depends on harmony in the relationship between local people and elements of the landscape. In both the Cabécar and the Quechua communities, the existence of these spiritual values is the basis for the conservation of other services such as those provided by biodiversity and water cycle and climatic regulation. With current globalization trends, change of habits, values, and beliefs can become important drivers affecting cultural services.

Educational services were assessed by Sweden SU, São Paulo, and Portugal. These sub-global assessments reported an increase in educational activities associated with social-ecological systems, due to increasing levels of awareness of the value and benefits of, and thus demand for, environmental education.

Thus it appears that the cultural services of tourism and recreation are in good condition and increasing, while local-scale services of a spiritual nature are more variable. Spiritual services vary from place to place and may undergo cycles of collapse and revival, depending on policies, interventions, and context-specific factors such as changes in leadership, making it difficult to identify trends. Spiritual values act as strong incentives for ecosystem conservation in many communities, as found in Vilcanota, Bajo Chirripó, India Local, and SAfMA. (See also Chapter 11.)

These conclusions must, however, be tempered with some degree of caution. The suite of cultural services assessed in the sub-global assessments is limited, with a major focus on tourism and some spiritual services. The definitions of cultural services and the sub-categories of these services are vague; furthermore these services are interrelated (for example, tourism services rely on aesthetic services). In addition to the uncertainty associated with the definition of various cultural services, there was a lack of appropriate data, indicators, and tools with which to assess them. Despite these limitations, the sub-global assessments provide a first picture of the importance and condition of cultural services across cultures, ecosystems, and continents.

8.4 Linkages and Trade-offs among Ecosystem Services

Ecosystem services are interdependent (Heal et al. 2001), that is, increasing the production of a service such as timber production may decrease that of another service such as carbon sequestration. In other instances, it is possible to increase the production of two ecosystem services simultaneously. This section focuses on some of the linkages among ecosystem services found by the sub-global assessments. It then presents frameworks developed and used by the sub-global assessments to communicate these linkages and trade-offs to decision-makers.

8.4.1 Examples from the Sub-global Assessments

One of the most complex examples of linkages among ecosystem services comes from the Laguna Lake Basin assessment. The establishment of fishpens and fishcages in the lake has had both positive and negative impacts on the fish provisioning service, and negative impacts on water quality and biodiversity. Pen and cage culture have contributed significantly to fish production in the lake. Net enclosures also provide indirect stocking for some open water fisheries (for

example, the Manila catfish, *Arius manillensis*); but they also led to the invasion of alien species, with negative impacts on the fisheries and biodiversity, including on two native catfish species (*Clarias batrachus* and *Hypostomus plecostomus*). Species diversity has declined significantly: of the 33 species (both native and alien) reported to have thrived in Laguna Lake at different times, only 5 out of the 14 native species have remained. Of these 14 native species, all 5 migratory species have disappeared and the catch at present is dominated by the alien species introduced for aquaculture. Aquaculture has also had a negative impact on the water quality of the lake, through the loading of nutrients in the form of unassimilated food and metabolic wastes, which add to the significant influx of nitrogen and phosphorus from agricultural activities (and domestic wastes). The high levels of phosphate and nitrogen trigger the occurrence of algal blooms that either kill or impart an off-flavor taste to fish (Laguna Lake Basin).

Many sub-global assessments reported declines in some ecosystem services that were related to the increase or utilization of other ecosystem services. In Southern Sinai, intensive agriculture has increased food security and income (through increased employment), but has also had some negative impacts on regulating services. Irrigation with the use of saline groundwater has resulted in the salinization of soils and decreases in productivity.

The Papua New Guinea assessment reported unsustainable use of mangroves for building materials and fuel, which resulted in loss of regulating (shore protection), supporting (nurseries), and provisioning (invertebrate fisheries) services. Oil palm and cocoa plantations also present substantial trade-offs between provisioning and supporting/regulating services. These crops have some negative impacts on soil fertility, soil structure, and pest and disease regulation (Hairiah et al. in press); but more importantly, certain smallholder schemes (for example, lease-back schemes used for oil palm) can result in negative impacts on human well-being (Koczberski et al. 2001). Oil palm plantations have also been the locus of introduction of exotic weed species (Casson 2003).

The trade-offs among ecosystem services, particularly between provisioning and regulating services, are often viewed from a field or plot-scale perspective, with the general conclusion being that when an area is harvested for food, fuel, or fiber, other services are lost. In fact, the utility of many ecosystem services, particularly the regulating services, often emerges at a landscape scale. As such, while specific parts of the landscape may provide food or fuel, other ecosystem services, such as water provision, pollination, and pest control, are provided more diffusely. The questions then become: what features of the landscape are needed to maintain those regulating services (for example, biologically-diverse communities, water infiltration), what proportion of the landscape must contain those features, and how should they be distributed across the landscape? Such questions pertain to the conversion of natural systems but also to the design of intensively-managed landscapes. These types of questions are relevant to integrated pest management (Landis et al. 2000; Thies et al. 2003), pollination ecology, and placement of buffer strips for soil erosion control and water quality, among others. The optimum configuration of the landscape so that all ecosystem services are maintained will not necessarily be the same as the configuration that would maximize individual ecosystem services, but often ''sufficient congruence'' may be achievable.

8.4.2 Frameworks and Decision-making Tools to Analyze Trade-offs

The use of ecosystem services often involves diverse actors with different values and competing objectives. The need to make choices among various ecosystem services, between specific ecosystem services and biodiversity, or between ecosystems services and human well-being is an inherent part of the decisions that ecosystem users and managers face. Trade-offs among ecosystem services may also occur temporally, through decisions about whether to reap benefits now or reserve them for future generations, or spatially, through use of an ecosystem service in a location affecting the condition of services in another location.

For example, the forests of the Western Ghats have historically been used intensively to meet local community needs, as well as for felling by the state forest department to meet regional needs for timber (Samraj et al. 1988). This resulted in a complex mosaic of relatively undisturbed forest, savanna, grassland, and barren patches, interspersed with monoculture plantations established by the forest department. Virtually all the major rivers in southern India originate in the Western Ghats. The changes in land use and land cover in the upstream catchments of these rivers are of critical importance to the millions of farmers on the eastern portion of the Deccan plateau, especially because of their increasing reliance on irrigation for the dependable production of food from high-yielding varieties. However, the watershed services of forests and associated ecosystems (such as grasslands) are poorly understood. Not all forests have similar influence on all watershed services. Nor do all non-forest land uses necessarily degrade these services. Because the non-wood services generate mostly indirect economic benefit, their value to society, and the distribution of this value, has not been properly quantified. Finally, there is no institutional mechanism by which the information on physical or socioeconomic impacts of land use change on watershed services can be fed systematically into decision-making. Typically, stakeholders are not informed about the science and policy of watershed management or afforestation. Thus, for example, eucalyptus trees were extensively planted on natural montane grasslands. This supports the requirements of industry for paper pulp and tannin, but reduces water yield from catchments by up to 23%, thereby affecting downstream hydropower projects. A lack of communication between foresters and scientists has allowed this trade-off, with a net adverse impact, to prevail.

The example above, while not coming directly from a sub-global assessment, illustrates that, faced with potential conflicts among objectives and users of ecosystem services, policy-makers need accurate, objective information to assist in their decision-making process. The information needs

to be presented in a way that allows them to weigh the implications and likely consequences of choosing among various options. Simply stating that fertilization or irrigation of agricultural fields pollutes rivers or compromises the longer-term sustainability of the soils and water supply is insufficient. There must be some means of assessing the magnitude or severity of the impacts or trade-offs of potential decisions.

Within the MA sub-global assessments, a range of techniques were used or developed to evaluate trade-offs in a transparent and informed manner. The methods used in the evaluation of tradeoffs in SAfMA Gariep and in the Tropical Forest Margins assessment are discussed here.

8.4.2.1 SAfMA Gariep: Two Approaches to Evaluating Trade-offs

Trade-offs in the southern African context typically involve the need to achieve social and economic development goals while securing ecosystem functions. In the Gariep basin, the challenge of evaluating trade-offs is intensified by the need to reverse past discrimination in South Africa that prevented the majority of the population from fully realizing or gaining access to the benefits provided by ecosystem services.

Several approaches were used to assess trade-offs among various aspects of the core ecosystem services assessed in SAfMA Gariep—water, food, and biodiversity. Two of these approaches and their results are discussed here.

8.4.2.1.1 Trade-offs between land use and biodiversity

Food production and biodiversity conservation have clashed in southern Africa, where the need to feed a growing and largely impoverished, undernourished population has more often than not been seen as more urgent than the need to conserve biodiversity. SAfMA Gariep used the notion of irreplaceability to assign comparable values to areas of land, based on specified targets of achieving food production and biodiversity conservation goals. Irreplaceability can be thought of as uniqueness: it is the likelihood that the site will be required as part of a network needed to achieve targets and the extent to which the options for achieving the set of targets are reduced if the site is unavailable (Pressey 1994). Several advantages of this approach make it an effective tool for communicating with decision-makers: it is flexible (targets can be set according to specific objectives), dynamic (targets can be updated as decisions are made), visual, and transparent.

SAfMA Gariep applied the irreplaceability concept to food services and biodiversity features. Food production was divided into two components: calorie production from cereal crops and protein from meat. Irreplaceability maps were generated for the Gariep basin based on targets for proteins, calories, and biodiversity. Irreplaceability values ranged from 0 (many options in other locations to achieve the goals) to 1 (totally irreplaceable, the goals for services would not be met if this location was not included). The trade-offs assessment then investigated those sites (represented as mapped grid cells) where there was more than one competing service or where there was conflict between conservation goals and one or more ecosystem services. No site was found to be totally irreplaceable for protein or caloric production, but several sites were totally irreplaceable for biodiversity. A land use plan would therefore optimize for conservation of the irreplaceable sites for biodiversity conservation, and allow grazing or cultivation on sites with low biodiversity irreplaceability. A potential trade-off situation exists at one site in the southeastern part of the Gariep basin, where biodiversity is totally irreplaceable and protein and caloric production are very highly irreplaceable.

8.4.2.1.2 Trade-offs between water and food production

As a consequence of new legislation, efforts to increase the productivity of agricultural water use in the Gariep basin by both commercial farmers and smallholders must aim to improve not only the economic efficiency of irrigation but also equity in water availability. The Podium model, a decision-support tool for policy dialogue, was developed by the International Water Management Institute to assess policy options related to national-level cereal-based food security and water availability in South Africa. The model provides an analytical framework for assessing water and food demand in 2025 resulting from population growth and changing diets. It focuses on four uncertainties: (1) population growth; (2) options for meeting food security through increases in irrigated area; (3) options for meeting food security through increases in the efficiency of irrigation water use or through yield improvements; and (4) the impact of increasing the daily water allocation per capita for basic human needs. The Kamara and Sally (2002) model applied to South Africa reveals that:

- Population growth above that projected under the United Nation's medium-growth estimate for 2025 (resulting in a population of approximately 48 million) will lead to threatened food security if water utilization, irrigation efficiencies, and crop yields remain stable.
- An increase of 40% in irrigated land area (equivalent to about 1.8 million hectares of total irrigated land area would be needed to achieve surplus food production if current yield levels and the trade balance remain unchanged. This would require an increase in total diversions of water, which would require huge financial investments that might not be easily realized.
- An increase in irrigation water use efficiency from 55% to 60% would reduce the degree of development of water resources by 4% and total diversions of water by 9%.

In summary, expanding irrigated area in isolation of other interventions is not likely to significantly improve food security. On the other hand, modest increases in irrigated area and improvements in efficiency are feasible and do not imply the need to allocate large amounts of water to the agricultural sector. This analysis, which focused only on cereal production at the national level (though most cereal production occurs within the Gariep basin), may obscure key trends that would emerge in studies of other crops or specific catchments.

8.4.2.2 The ASB Matrix

Land and resources at the tropical forest margins are used by several sets of users. Forest dwellers, following their tra-

ditional ways of life based on hunting and gathering, are losing their land to migrant smallholders. These smallholders clear small amounts of forest for crops and livestock, and are concerned with food security, property rights, and the profitability of their farms. Both forest dwellers and smallholders tend to lose out to more powerful groups—ranchers, plantation owners, large-scale farmers, and logging companies—who are engaged in large-scale commercial exploitation of forests. This exploitation is driven by international consumer demand for wood and for other products from land which has been cleared of forest. Outside the forests, there is also an international community that wishes to see forests preserved as sinks for carbon, which would otherwise contribute to climate change, and for the biological diversity they harbor.

Deforestation continues because converting forests to other uses is almost always profitable for the individual. However, society as a whole bears the costs of lost biodiversity, climate change, smoke pollution, and degraded water resources. Every year, the world loses about 12 million hectares of tropical forest (FAO 2001). No land use system replacing this natural forest can match it in terms of biodiversity richness and carbon storage. However, land use systems vary greatly in the degree to which they combine at least some environmental benefits with their contributions to economic growth and livelihoods of the poor. It is, therefore, always worth asking what will replace forest (and for how long), both under the current mix of policies, institutions, and technologies and compared to possible alternatives. In other words, what can be done to secure the best balance among the conflicting interests of different groups?

Researchers of the Alternatives to Slash-and-Burn consortium (the Tropical Forest Margins assessment is a program component of the ASB consortium) developed a framework known as the ASB matrix to help evaluate the local, national, and global impacts of alternative land use systems practiced at the tropical forest margins and to guide policy decisions (Tomich et al. 1998; Tropical Forest Margins). In the ASB matrix, natural forest and the land use systems that replace it are scored against various criteria reflecting the objectives of different interest groups. To enable results to be compared across sites, the land use systems specific to each site were grouped according to broad categories, ranging from agroforests to grasslands and pastures. The criteria for evaluating the ecosystem services may be fine-tuned for specific locations, but the matrix always comprises indicators for the following:

- two major global environmental concerns on regulating services of ecosystems—carbon storage and biodiversity;
- agronomic sustainability, assessed according to a range of soil ecosystem services, including trends in nutrient cycling and organic matter over time;
- smallholders' livelihood concerns, including their workload, returns on their labor, food security for their family, and start-up costs of new systems or techniques;
- policy objectives, including economic growth and employment opportunities; and
- policy and institutional barriers to adoption by smallholders, including the availability of credit, markets, and improved technology.

Over the past eight years, ASB researchers have calculated this matrix for representative benchmark sites across the humid tropics. The social, political, and economic factors at work at these sites vary greatly, as do their current resource endowments: from the densely populated lowlands of the Indonesian island of Sumatra, through a region of varying population density and access to markets south of Yaoundé in Cameroon, to the remote forests of Acre State in the far west of the Brazilian Amazon, where settlement by small-scale farmers is relatively recent and forest is still plentiful. At each site, ASB researchers evaluated land use systems both as they are currently practiced and in the alternative forms that could be possible through policy, institutional, and technological innovations.

The matrix allowed researchers, policy-makers, environmentalists, and others to identify and discuss trade-offs among the various objectives of different interest groups. The studies in Indonesia and Cameroon revealed the feasibility of a "middle path" of development involving smallholder agroforestry and community forest management for timber and other products. Such a path could deliver an attractive balance between environmental benefits and equitable economic growth. "Could" is the operative word, however, since whether or not this balance is struck in practice will depend on the ability of these countries to deliver the necessary policy and institutional innovations.

Take the examples of Sumatran rubber agroforestry plots (Table 8.5) and their cocoa and fruit counterparts in Cameroon. These systems offer levels of biodiversity which, though not as high as those found in natural forest, are nevertheless far higher than those in monocrop tree plantations or annual cropping systems. Like any tree-based system, these systems also offer substantial levels of carbon storage. Technological innovations have the potential to increase yields of the key commodities in these systems, thereby raising farmers' incomes substantially, to levels that either outperform or at least compete well with virtually all other systems. (It is also interesting to note that several tree-based systems in Cameroon have similar levels of carbon storage but drastically different profitability and hence attractiveness to farmers.)

The Brazilian Amazon, in contrast, presents much starker trade-offs between global environmental benefits and the returns on smallholders' labor. Here the most commonly practiced pasture-livestock system, which occupies the vast majority of converted forest area, is profitable for smallholders but entails huge carbon emissions and biodiversity loss. Systems that are preferable from an environmental point of view, such as coffee combined with *bandarra* (a fast-growing timber tree), can pay better, but have prohibitively high start-up costs and labor requirements and are riskier for farmers. An alternative pasture-livestock system, in which farmers are expressing interest, offers even higher returns on land and labor but only slightly improves biodiversity and carbon storage. In other words, the land use alternatives that are attractive privately are at odds with global environmental interests. Only a radical overhaul of the incentives facing land users—including smallholders—could change things.

Table 8.5. ASB Summary Matrix for the Indonesian Benchmark Sites (Tropical Forest Margins). "nm" indicates not measured; "n.a." indicates not applicable. For *agronomic sustainability*: 0 indicates no difficulty, −0.5 indicates some difficulty, −1 indicates major difficulty. *Returns to labor and land* are output prices based on ten-year (1988–1997) averages, expressed in real US$ in 1997 (US$ = Rp 2400 in 1997), discounted at 20% per annum. For *household food security,* "consumption" and "$" reflect, respectively, whether the technology generates food for own-consumption or income that can be used to buy food, or both. Note (a): social prices rather than private prices; "social prices" means adjusted for factor market and trade policy distortions; however, values have not been adjusted for environmental externalities or public goods.

	Global Environmental Concerns		Agronomic Sustainability			National Policymaker Concerns		Smallholders Concerns/ Adoptability by Smallholders	
	Carbon storage	Biodiversity	Plot-level Production Sustainability			Returns to Land	Labor Requirements	Returns to Labor	Household Food Security
Land Use Systems	Aboveground tC/ha (time-averaged)	Aboveground plants (# species per standard plot)	Soil structure	Nutrient Export	Crop Protection	$/ha (private prices)	Labor person-days/ha/yr	$/ person-day (private prices)	Means of household access to food
Forest	306	120	0	0	0	0	0	0	n.a.
Community-based forest management	120	100	0	0	0	5	0.2 to 0.4	4.77	$ + consumption
Commercial logging	94	90	−0.5	0	0	1,080 (a)	31	0.78	$
Rubber agroforest	79	90	0	0	−0.5	0.70	111	1.67	$
Rubber agroforest with clonal planting material	66	60	−0.5	−0.5	−0.5	878	150	2.25	$
Oil palm	62	25	0	−0.5	0	114	108	4.74	$
Upland rice/bush fallow	37	45	0	−0.5	−0.5	−62	15 to 25	1.47	consumption
Continuous cassava/ imperata	2	15	−0.5	−1.0	−0.5	60	98 to 104	1.78	$ + consumption

8.5 Synthesis

Three main approaches to assessing the condition of ecosystem services emerged from the work of the sub-global assessments. The first, more classical approach was to report the values for a set of indicators and the typical or baseline values for those parameters. Comparisons among assessments can be made when the same set of indicators is used and when there is agreement on the baseline values. A second approach was to classify the condition of ecosystem services on a qualitative scale; it is similar to the first approach, but can also use other types of data and resort to expert opinion. Comparison among assessments is possible when the qualitative categories have been defined similarly in the different assessments. A third approach was to compare the supply of and the demand for ecosystem services. This approach is limited to services that involve some type of commodity (for example, water provisioning, food production, recreation) and is more useful at coarse scales. At fine scales, ecosystem services consumed in a given area are often produced somewhere else, and further analysis such as the ecological footprint (Wackernagel et al. 2002) becomes necessary.

While some data exist on the production of some provisioning services and cultural services, data are generally lacking on the natural capacity of ecosystems to continue to provide those services, as well as regulating and supporting services. There is an urgent need for long-term studies monitoring a common set of indicators of the condition of ecosystem services. In the case of biodiversity, although most of the sub-global assessments assessed biodiversity, historical data were insufficient to perform a quantitative analysis of trends.

The different approaches used to assess the condition of ecosystem services also reflected different interpretations of what is meant by the condition of an ecosystem service. Some assessments assessed the ecological capacity of the system to provide the service (for example, Portugal) while other assessments emphasized the production of and demand for the service (for example, SAfMA) and equity of access to the service (for example, Sinai). These differences in emphasis were partially correlated with the socioeconomic development of the areas being assessed: issues of equity and production versus demand for a service were not the main focus of the assessments in industrial countries (Portugal, Norway, Sweden).

The contrast between the emphases on ecological capacity and production/consumption occurred only in marketed services such as provisioning and cultural services, and can be illustrated with the cultural service of recreation.

Several sub-global assessments reported a positive trend for the recreation service because numbers of tourists are increasing (the production and the consumption of the service are increasing). However, in Portugal, despite increases in the number of tourists in the coastal areas over the last few decades, there has been a degradation of those areas caused by the development of tourism infrastructure; therefore, the ecological capacity of that system to attract and support tourism has decreased. So reporting a positive trend for a service can have different meanings across different sub-global assessments.

Assessing trends in the condition of a service can be simpler than evaluating the current condition of the service. Evaluating the condition of a service (for example, on a qualitative scale from bad to excellent) requires a baseline for comparison. Baselines used by sub-global assessments included the distant past (for example, 100 years in the Norway assessment, pre-industrial times in SAfMA) and a concept (for example, current level of the capacity of the ecosystem to provide the service relative to the level at which the service could be maximized in a sustainable way in Portugal). In contrast, a trend only requires any two data points in time (for example, two successive decades).

Choosing appropriate units for assessment is key both for each assessment and for comparison across assessments. The MA conceptual framework (MA 2003, p. 54–55) proposed ten global reporting categories (Marine, Coastal, Inland Water, Forest, Dryland, Island, Mountain, Polar, Cultivated, and Urban) that were also used as the basic reporting categories in some sub-global assessments (Portugal, Norway). These global reporting categories overlapped partially, and most consisted of a range of ecosystems that shared a suite of biological, climatic, and social factors. Other assessments chose other reporting categories tailored to their region. For instance, the Altai-Sayan assessment studied the forests of the Altai republic and the grazing ecosystems of Western Mongolia, while the Colombia assessment studied the coffee-growing region of Colombia.

The advantages of the assessment-specific reporting categories are that they encompass homogeneous social-ecological regions at a given scale, that provide a bundle of ecosystem services to the population, in contrast with global categories such as forests, that can span very different social-ecological systems. Furthermore, tailoring the reporting categories to each assessment can facilitate the use of data previously collected by local or national authorities. However, if the focus of the assessments is on comparability across locations and spatial scales, standard reporting categories should be adopted. The Portugal assessment solved this problem by using the global reporting categories, but redefining the units where needed to make them compatible with national inventories, and in one instance creating a new category for a social-ecological system of national importance (the *montado*).

The sub-global assessments highlighted that several ecosystem services are in fair to poor condition and declining (Appendix 8.1). Despite some gains in the production of provisioning services, the ecological capacity of the systems to continue to provide these services is at risk in several locations. Problems with provisioning services include deterioration of water quality, deterioration of agricultural soils, and incapacity of supply to meet demand. Problems with regulating services include loss of forest cover and fire frequency. Problems with cultural services include loss of cultural identity and negative impacts from tourism. Problems with biodiversity include loss of area of native habitats and decreasing population sizes, particularly of species that have large body mass or occupy high trophic levels and species that are harvested by humans. A meta-analysis of water provisioning and biodiversity illustrates congruence of results between global and sub-global assessments.

Land use change is the most important driver of change for provisioning, supporting, and regulating services and for biodiversity. Indirect drivers are particularly important for provisioning and cultural services because they control the patterns of demand for those services. Some direct drivers of ecosystem change were also indicators of the condition of the service (for example, harvest pressure for biodiversity). While human controlled drivers play a major role in the condition of ecosystem services, local biophysical constraints such as climate and soils also limit the production of ecosystem services.

Clear trade-offs exist among ecosystem services. The analyses performed by the sub-global assessments, in agreement with global results, generally showed an increase in provisioning services at the expense of regulating services, supporting services, and biodiversity, or at the expense of the capacity of the ecosystems to provide services to future generations. Trade-offs can also occur between provisioning services such as irrigated agriculture and freshwater provisioning. New approaches such as the ASB matrix were developed to communicate and discuss these trade-offs with policy-makers.

Links between human well-being and ecosystem services can be difficult to uncover due to the lack of markets for some services, as well as the spatial disconnect between the supply and the consumption of ecosystem services. (See Chapter 3.) Nevertheless, the sub-global assessments improved understanding of how human well-being depends on ecosystems in several ways. First, the sub-global assessments produced inventories of the bundle of services that ecosystems provide in different parts of the world, such as the different types of food produced, the different uses for water, the variety of cultural services, etc. Second, by emphasizing the sustainability of the service and the classification of the condition of ecosystem services, the sub-global assessments uncovered trade-offs among different services. Third, in some instances, economic values of ecosystem services were estimated, providing valuable data at scales relevant for decision-making. Fourth, in the community assessments where participatory approaches were used, much was learned from the local communities about the connection between ecosystems and human well-being. (See Chapter 11.) Finally, the work of the sub-global assessments increased the prospects of furthering understanding of how human well-being depends on ecosystem services by building local capacity for this type of analysis, and highlighting

the need for monitoring the condition of ecosystem services at the local, regional, and global levels.

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Appendix 8.1. Qualitative Assessment of Condition and Trends: Biodiversity and Provisioning, Regulating, Supporting, and Cultural Services in Selected Sub-global Assessments. Based on expert opinion from the assessment teams as described in assessment reports, answers to survey questionnaires, and interviews in knowledge markets. Condition (C) is classified based on a numerical scale from 1 (poor) to 5 (excellent). Trends (T) can be decreasing (−), stable (0), or increasing (+). Comment columns include information on how services were assessed, with caveats in some cases.

	Biodiversity			Soil Formation			Climate Regulation			Flood Protection			Fresh Water			Food			Fuelwood and Fiber			Cultural Services		
Sub-global Assessment	**C**	**T**	**Comment**	**C**	**T**	**Comment**	**C**	**T**	**Comment**	**C**	**T**	**Comment**	**C**	**T**	**Comment**	**C**	**T**	**Comment**	**C**	**T**	**Comment**	**C**	**T**	**Comment**
Altai-Sayan	3	−	good in forest, poor in steppe	3	−	water and wind soil erosion	2	−	albedo and other landscape properties	4	0		4	−		3	−	based on steppe condition	4			4	−	threatened due to tourism and economic development
San Pedro de Atacama	3	−	number of species										2	−	quantity of groundwater	3	−	agricultural production				5	+	increasing mass tourism, increasing special interests tourism
Caribbean Sea	1	−	live coral cover													2	−	fish landings				5	+	tourism, GDP, employment
India Local	4	−	conservation status, number of species										3	−	quantity (4), quality(3)	3	−	forest foods	3	−	fuelwood (3,-) and fiber (3,0)	4	+	
Norway	3	−		2	−					3	−		4	−	quantity and quality	3	0		3	0		3	0	
PNG	4	−	coral reefs																					
Laguna Lake Basin	2	−	number of species				3	−	greenhouse gas emissions				2	−	quality: levels of coliform bacteria, dissolved oxygen and pollutants; quantity: lake depth	2	−	fish landings (3), rice area (2)						
Portugal	3	−	native habitat cover, number of species, population sizes	3	0	agricultural practices, fire frequency, vegetation cover	3	+	carbon sequestration (tree cover, fire frequency)	3	−	wetland area, tree cover in basins	3	+	surface and underground water quality; some recent positive trends	4	0	fertilizer/pesticide use, pelagic stocks, aquaculture	3	0	sustainability of cork and timber production	3	0	ecological capacity for recreation; offer and demand are increasing
SAfMA G-M (Gorongosa)	4	−	number of ecosystems										5	0	supply minus demand	3		supply minus demand; heterogeneous in space and time						
SAfMA Gariep	3	−	number of species, vegetation types, irreplaceability				3	−	carbon dioxide and sulfur dioxide emissions				2	−	mean annual runoff, runoff per capita, access to water services production	3	0	livestock and cereal production						

SAfMA Regional	4	–	biodiversity intactness index, forest area				4	–	ozone concentration				3	–	quantity (4): cubic meters per capita, heterogeneous in space; quality (3): diarrhea rates	2	–	protein per capita, calories per capita (3, 0)	4	0	cubic meters per capita (supply minus demand), heterogenous	4	+	increasingly recognized (tourism, biodiversity, heritage), but threatened by globalization
Northern Range	3	–	expert opinion							3	–	runoff flow and flooding	3	–		3	–	fish stocks	3	–		4	–	amenity value
Tropical Forest Margins																								
Acre, Brazil	4	–	aboveground plant	4		nutrients	5	–	carbon	5			5		quantity	5			5		timber			
Rondonia, Brazil	2	–	biodiversity	3			3	–	sequestration	5			5			5			4					
Ebolowa, Cameroon	5	–	measured as	5			4		(aboveground)	5			5			5			4					
Yaounde, Cameroon	3	–	number of species	4	–		3	–		5			5			5			3					
Jambi, Indonesia	4	–	and functional	4	–		4	–					5			5			3					
Lampung, Indonesia	1	–	types	2	–		2	–					5			5			1					
Downstream Mekong	3	–	wetland area	2	–	decrease in alum-washing process							4	0	supply minus demand	4	+	agriculture production, fish landings	3	+		4	+	increase in ecotourism, recreation
Western China—NW	2	+		2	+	desertification, soil	4	–	carbon				2	–	surface and	4	+							
Western China—SW	4	–		4	0	erosion	4	–	sequestration				5	0	groundwater	4	0							
Bajo Chirripó	3	0	hunting pressure, timber harvest, biodiversity index, forest cover; heterogeneous across taxa	4	0					4	0	in the lowlands wetlands have disappeared	4	–	condition of water springs in the dry season							5	0	
Eastern Himalayas	4	–	number and distribution of species	2	–	soil erosion							3	–	quantity: run off; quality: turbidity	3	+	quantity						
Sinai	3	–	number and distribution of native species										3	–	quantity: precipitation rate, distribution per capita; quality: salt concentration, infectious diseases	3	–	type of crops, cultivation area, total production						
India Urban	3	0	habitat quantity and quality, number of species, harvest pressure; heterogeneous across taxa				1	–	carbon sequestration (green cover)				1	–	physico-chemical analysis, biological indicators	3	0	market analysis				3	–	loss of wilderness areas; loss of cultural values
São Paulo	4	–	number of species, vegetation cover				3	–	forest surface, vegetation type and growth	4	–	landslides, sediments	3	–	quantity (2): supply minus demand; quality (3): eutrophication level	3	–	production and markets	3	+	reforested area, management systems	4	+	visits to protected and other green areas

Chapter 9

Responses to Ecosystem Change and to Their Impacts on Human Well-Being

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Main Messages ***207***

9.1 Assessing Sub-global Responses: Focus and "Lenses" Used **208**
9.1.1 Response Features, Complexity, and Choices
9.1.2 Institutions and Responses
9.1.3 Resilience of Social-ecological Systems
9.1.4 Selection of Responses and Methods for Assessing Effectiveness

9.2 The Sub-global Findings on Responses **211**
9.2.1 The Complexity of Sub-global Responses
9.2.2 The Spatial Reach and Effectiveness of Sub-global Responses
9.2.3 The Dynamic Nature of Responses
9.2.4 The Effectiveness of Multilevel Responses

9.3 Impacts and Effectiveness: Lessons Learned **215**
9.3.1 Collaboration: The Interplay of Informal and Formal Institutions
9.3.2 "Bridging Organizations" Facilitate Multiscale Collaboration
9.3.3 Economic and Social Incentives
9.3.4 The Reach of Sub-global Responses
9.3.5 Synergy and Coherence
9.3.6 Technology and the MA Conceptual Framework

9.4 Lessons Learned for Future Assessments **220**

APPENDIXES

9.1 Thirty-seven Important Responses Reported by Different Sub-global Assessments **222**

9.2 Features of the 37 Most Important Responses Reported by the Sub-global Assessments **225**

REFERENCES **227**

BOXES

9.1 Responses and Social-ecological System Resilience

9.2 Taking Advantage of Policy Windows: Sweden KW and South Africa

9.3 Bottom-up and Top-down Collaboration: Sweden KW, Laguna Lake Basin, and India Local

9.4 Wildlife Management Areas in Papua New Guinea: A Colonial Response with Unexpected Results

9.5 Public and Private Sector Actions: San Pedro de Atacama

9.6 Government–Community Co-management of a Sea Urchin Fishery: St. Lucia, Caribbean Sea

9.7 Aggregated Responses: São Paulo and Sweden SU

FIGURES

9.1 Four Features Used for Assessing Sub-global Responses: Multiplicity of Actors, Organizational Levels, Knowledge Systems, and Instruments of Action

9.2 Responses Using National Legislation as an Instrument May Be Different in Features and Complexity

9.3 Four Features of Responses for Three Sub-global Responses Where Bridging Organizations Played a Major Role

Main Messages

Declining ecosystem trends have been halted, and in some cases reversed, by innovative local responses. The "threats" observed at an aggregated, global level may be overestimated or underestimated from a sub-global perspective. Assessments at an aggregated level often fail to take into account the adaptive capacity of sub-global actors. Through collaboration in social networks, actors can develop new institutions and reorganize to mitigate declining conditions. On the other hand, sub-global actors tend to neglect drivers that are beyond the reach of their immediate influence when they craft responses. Hence, it is crucial for decision-makers to develop institutions at the global, regional, and national levels that strengthen the adaptive capacity of actors at the sub-national and local levels, so that context-specific responses that address the full range of relevant drivers may be developed. This means neither centralization nor decentralization, but instead institutions at multiple levels that enhance the adaptive capacity and effectiveness of sub-national and local responses.

All policy tools (instruments for executing responses) are by definition implemented in a specific institutional context. A focus on strengthening adaptive capacity and institutional interaction is more important than assessing individual policy tools in isolation. The sub-global assessments provided clear examples of various instruments for executing responses. The potential effectiveness of each instrument is increased if general legislation and economic incentives provide an enabling institutional framework, if a blend of scientific and more context-specific knowledge systems is used in crafting the response, if the dominant value system acknowledges the complexity of ecosystem dynamics, and if institutional interaction is benign. Natural resource management always involves conflicting interests, and the main lesson learned from this assessment of responses is that innovative ways of collaboration and conflict resolution, together with a reasonable legal and economic framework, are often crucial for effective responses.

The effectiveness of a response seems correlated to the degree of coherence among different types of policies and the degree of collaboration among stakeholders. Horizontal (multisector) collaboration ensures that multiple objectives (ecological, social, cultural, economic) are addressed in an integrative fashion. Vertical (multilevel) collaboration facilitates generation of resources and increases the probability that responses have a positive impact on the direct and indirect drivers of ecosystem change. Since these drivers typically occur at a continuum of social and ecological scales, responses would need to involve decision-makers (and action takers) at multiple organizational levels. For instance, local responses such as coping and adapting to environmental change among the Bedouins in Egypt and local communities in southern Africa have been largely ineffective due to the lack of institutional and financial support at the national level. In contrast, local people in the Eastern Himalayas took the initiative to form Eco-Development Committees, and this became an effective response. Collaboration, therefore, is not only a local phenomenon; it has been initiated by all categories of actors operating at all identified organizational levels.

Research institutions and the business sector initiated very few of the responses reported by the sub-global assessments. More often, they became involved in the responses at a later stage. Response initiatives by research institutions were found to be focused on initiating collaboration with other stakeholders. Examples of response initiatives by the business sector are found in Northern Range, Trinidad, where two banks initiated environmental projects with long-term commitment, and in Portugal, where the pulp and paper industry has taken voluntary initiatives to improve its forestry management.

Multiple drivers of ecosystem change have been addressed by integrated policies as well as targeted responses. To be effective, responses often need to address a range of drivers and interactions of human and ecological systems. Sometimes responses need to occur as a chain of actions to match the reach and interactions of the drivers of change. For instance, the new government policy for Western China is an integrated response including a series of interventions to combat poverty while at the same time halting current declining trends in several ecosystems. On the other hand, in some cases, a targeted action appears more effective, as illustrated by the South African Water Act of 1998, which was an effective response to several conflicts and drivers.

A set of responses may be mutually strengthening and reinforcing, but could undermine each other if they lack coherence among themselves. Institutional coordination is crucial to create enabling conditions. For instance, actors with different authorities or mandates may have potentially high organizational and institutional capacities for effective responses, but this potential may not be realized due to the inability to coordinate actions among actors at the same or different organizational levels. One example of this is various citizen actions to halt urban sprawl in Stockholm, Sweden. These actions have been supported by decision-makers at municipal and higher organizational levels. However, due to compartmentalization, decision-making is divided between different sectors, resulting in inconsistent policy proposals (conservation versus development). In this case, the administrative structure inhibited effective conflict resolution.

Collaboration among actors is often facilitated by "bridging organizations." These provide arenas for multisector and/or multilevel collaboration for conceiving visions, trust-building, collaboration, learning, value formation, conflict resolution, and other institutional innovations. Bridging organizations lower the transaction costs of collaboration and crafting effective responses. They provide social incentives to identify unique win-win responses. The facilitation, leadership, and social incentives provided by bridging organizations or key persons in the community appear to be essential for capacity-building. The following three examples illustrate the formation of bridging organizations resulting from bottom-up, top-down, and external initiatives, respectively: (1) in Kristianstad Wetlands, Sweden, a new organization called Ecomuseum has initiated a process based on collaboration, trust-building, and conflict resolution; voluntary participation within the existing legal framework is transforming a declining area into a UNESCO Biosphere Reserve; (2) in the Laguna Lake Basin, Philippines, public agencies and nongovernmental organizations formed River Rehabilitation Councils that have been able to address social and ecological drivers in a collaborative and effective way; (3) in San Pedro de Atacama, Chile, the assessment team provided an arena for collaborative learning, trust-building, visioning, and conflict resolution.

Insights from sub-global assessments are extremely useful if one wants to understand the social dynamics underlying effective responses. Social, behavioral, and cognitive changes were involved in half of the reported sub-global responses. Conflicting world-views (assumptions about the relationships between humans, nature, and society) often underlie and explain conflicts over natural resource management. Hence it seems reasonable to address these issues in responses as well as in assessments of responses. The dynamics of "bridging organizations" and the fine-grained interplay between formal and informal institutions are only discovered in sub-global assessments. These dynamics underlie the adaptive capacity of sub-global actors to mitigate declining conditions and trends of ecosystem services observed at an aggregated level. In several cases, research institutions and assessment teams have enhanced this capacity (for example, in the Tropical Forest Margins assessment, where land and tree tenure reform in Indonesia was facilitated by the Alternatives to Slash-and-Burn program of the CGIAR).

When people with different interests, experiences, and knowledge cooperate across organizational levels, the diversity of response options increases and this enhances the potential effectiveness of responses. Besides the democratic appeal of public participation, the knowledge base is broadened when local, traditional, and indigenous knowledge systems are acknowledged. By close monitoring of a diverse set of ecological variables, local stewards are often able to observe and understand early signals of ecosystem change and to distinguish this from natural variability. In Kristianstad Wetlands, Sweden, for example, local steward organizations observed declining bird populations and other signals that sparked the formation of a bridging organization. Successful integration of different knowledge systems underlies several of the effective sub-global responses; for example, the Mangrove Marine Reserve in the Caribbean Sea resulted from collaboration between an NGO and local users that was aimed at meeting the needs of local users for fuelwood.

9.1 Assessing Sub-global Responses: Focus and ''Lenses'' Used

The MA conceptual framework suggests that responses occur when ecosystem changes and their effects on human well-being are perceived to pose either opportunities or threats to the well-being of societies and communities (MA 2003). The responses observed in the MA sub-global assessments offer insights on the variety of ways in which people respond to these changes. As used in this chapter, ''sub-global responses'' pertain to responses observed in the particular places and times of each sub-global assessment. In this sense, a sub-global assessment is itself a ''response.''

This chapter assesses four features of responses to ecosystem change that are also used elsewhere in the MA process to characterize responses. (See Chapters 5 and 11 in this volume, and also Chapters 2 and 15 in MA *Policy Responses*.) It then examines the findings from the assessment of sub-global policy responses, as well as the lessons that can be learned from the process.

9.1.1 Response Features, Complexity, and Choices

The sub-global assessments reported a diversity of responses that may be assessed according to four features:

- The *actors* initiating and executing/implementing the responses vary among the sub-global assessments. At least six categories of actors were observed: (1) governments at national and/or sub-national levels; (2) international and national organizations other than governments; (3) research institutions; (4) the business sector; (5) communities (which include local civil society organizations, leaders, and sometimes local governments); and (6) individuals and households. This categorization of actors resulted from an iterative process adapted to the contexts described by the sub-global assessments. This is consistent with observations from elsewhere; examples include Imperial and Hennessey (2000) on ''portfolio of actors''; Ayudhaya and Ross (2000) on ''shared vision'' of different actors as being critical to the success of watershed management in Thailand; Dangbegnon (1996) on resource management in Lake Aheme, Benin; and Clarke (1998) on how NGOs affect policy in Asia.
- The *organizational levels* at which actors initiate or execute responses may either be (1) local, (2) sub-national, (3) national, (4) regional, or (5) global, or a combination of these levels.
- The *knowledge systems* of the actors are referred to in one of three ways: (1) scientific knowledge (the use of formal methods of science); (2) local knowledge (based on site-specific experiences of the actors); and (3) traditional/indigenous knowledge (based on how a particular community of actors has, over generations, uniquely accumulated a combination of knowledge and practices that is now embedded in their culture). (See Chapter 5 for a more detailed discussion of these knowledge systems; the categories and definitions given here are for the limited purpose of referencing the degree to which knowledge systems are used and combined in a response.)
- The *instruments* for executing/implementing responses may come in any of five categories that may be combined in a single response: (1) interventions directly affecting the resource base and state of ecosystems (direct human actions on ecosystems such as reforestation); (2) technological innovations/dissemination (using techniques yet unused to address a problem); (3) statutory (legal) devices and economic incentives; (4) organizational devices (the formation of new entities for collaboration among actors); and (5) social, behavioral, and cognitive change (for example, reorientation of values). (See similar discussions in MA *Policy Responses* and in the MA conceptual framework.)

A response involving *multiple* actors, levels of organization, knowledge systems, and instruments of action can be recognized as being more complex than one that involves less. Increasing the complexity of a response (for example, through stakeholder collaboration) may be adequate to address the complexity in governing common-pool resources (Dietz et al. 2003), but this entails a variety of costs (social, political, financial, economic, and technological; for example, see Allen and Schlager 2000; Saxena 1997); these costs imply that a response's degree of complexity will demand a corresponding level of resources from actors to initiate and implement that response. The choice made in relation to the degree of complexity could determine the extent to which a response can be sustained (for example, see Baland and Platteau 1996; Bebbington 1997; Contreras 2003; Magno 2001; Ostrom 1999).

An alternative interpretation of complexity would be to focus on the *content* of a response. But this would entail a very elaborate and detailed study of individual responses, which would be difficult since many MA sub-global assessments were not yet complete at the time of writing this report. This chapter therefore focuses on the *complexity* of a response with reference to its four features. (See Figure 9.1.) However, sometimes so many actors and instruments are involved in a response that it may be more reasonable to view its complexity as one body of several interrelated responses (see discussion below).

From the outset, there was no *a priori* assumption made about the merits of complex responses. It is only acknowledged that the responses observed and reported in the sub-

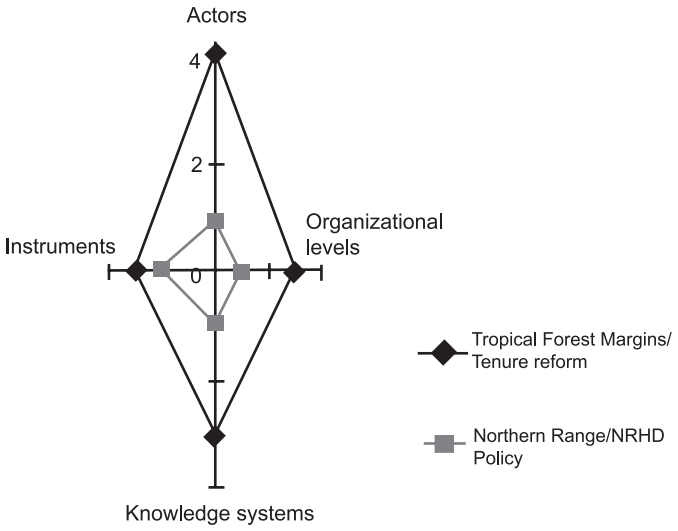


Figure 9.1. Four Features Used for Assessing Sub-global Responses: Multiplicity of Actors, Organizational Levels, Knowledge Systems, and Instruments of Action. In this chapter a complex response is defined as one involving several actors, organizational levels, knowledge systems, and instruments of action. The tenure reform of the Tropical Forest Margins Assessment was an effective response, thanks to good collaboration among several actors at several organizational levels acknowledging several knowledge systems and using many instruments of action. The NRHD Policy of Trinidad (Northern Range) was good but suffered from lack of collaboration, which impeded implementation and was therefore ineffective (see Appendixes 9.1 and 9.2). However, low complexity need not impede effectiveness (see Figure 9.2).

global assessments can be appreciated—and assessed—for patterns, trends, and lessons presented by their complexity.

9.1.2 Institutions and Responses

Responses always take place in the context of legal arrangements (formal institutions) as well as social norms and conventions (informal institutions). The collective infrastructure of regulations, organizations, markets, technology, culture, and traditions shape the reach and limits of what people can, may and must do in a given place and time, under certain conditions of their environment (see, for example, Edmunds and Wollenberg 2003 on devolution and forest resource management; Fischer et al. 2002 on mitigating agricultural vulnerability from climate change; Allen and Schlager 2000 on covenant institutions; and Bruns and Meinzen-Dick 1998 on legal pluralism). Rules and norms form economic and social incentives by rewarding or punishing environmental degradation (ENRAP 1996). Institutions play a role in the initiation and execution of responses, including by determining the distribution of transaction and other costs (North 1990). In turn, responses alter the institutional arrangements that define the choice sets of individuals and groups (Bromley 1990). Institutions provide the enabling conditions for (or present bottlenecks to) the successful initiation and execution of responses.

When actions are combined, the norms, standards, and rules that govern each one come into critical play. They may either facilitate or hinder the ability of the actions to complement one another (for example, see Liu 2001; Utting 2000; Johnson et al. 2001; Imperial and Hennessey 2000; Ostrom 1999; Bruns and Meinzen-Dick 1998; Oram 1991). Institutions can operate at local levels (for example, among artisanal fishers in Lake Benin; see Dangbegnon 1996) or at global levels through treaties and international agreements (for example, UNCED 1992 and WSSD 2002).

In the MA context, ''freedom'' is related to the options and choices for action offered by institutions (rules and social norms) and by the condition of ecosystem services. Freedom and the condition of ecosystem services can be positively or negatively related. Institutions that protect ecosystem integrity in order to sustain ecosystem services (for example, carbon taxes) contribute positively to long-term human well-being. However, such institutions are popularly described as decreasing the freedom of the present generation to maintain its material standard of living. The freedom of the present generation may need to be compromised if the aim is to maintain freedom, opportunity, and human well-being for future generations. If this is the case, institutions should be evaluated according to how well they increase the social capacity to sustain the ecosystem services necessary for long-term human well-being. The challenge, it appears, is to develop a fine interplay between formal and informal institutions in order to minimize the perceived trade-offs between short-term and long-term freedom (discussed further below).

9.1.3 Resilience of Social-ecological Systems

This assessment recognizes that sub-global responses are best understood when viewed in the context of the particular social-ecological system in which they take place. The ability of a system to absorb shocks (as might come from changes in its social and ecological components) could determine the choice of responses made. Hence, in this assessment, it is assumed that effective responses (responses that affect existing conditions and trends of ecosystem services and human well-being) involve addressing ecological and social dynamics together. The system of analysis is neither natural nor social but a linked social–ecological system. (See Box 9.1.)

9.1.4 Selection of Responses and Methods for Assessing Effectiveness

The MA sub-global assessments reported over 50 responses observed at their assessment sites. Thirty-seven (37) responses from 18 sub-global assessments were deemed sufficiently described for the purposes of this chapter. The sub-global assessment teams were asked to justify the selection of responses: why were the identified responses important? The most common answer was that the response addressed pressing ecosystem issues, often in a comprehensive or holistic way (as stated by the assessment teams). The justifications for each of the selected responses are stated in Appendix 9.1, which also summarizes the key issues addressed in each sub-global assessment and briefly describes the 37 responses selected for analysis in this chapter.

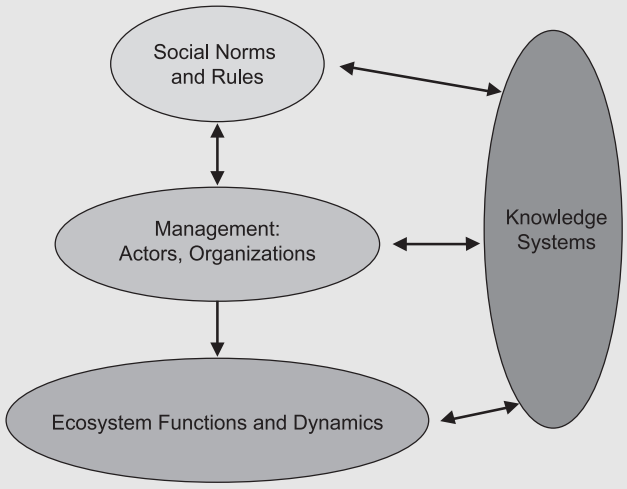
BOX 9.1

Responses and Social-ecological System Resilience

The concept of resilience is tightly connected to the diversity and the sustainability of social-ecological systems (Gunderson and Holling 2002; Berkes et al. 2003; Lele 2000). Responses that increase losses of diversity may pave the way for sudden drastic switches and stochastic events like shocks and surprises (Scheffer et al. 2001). Resilience has three defining components (Gunderson and Holling 2002):

- the capacity to absorb shocks or disturbances (while retaining the same controls on function and structure);
- the capacity to self-organize (to reorganize endogenously, in the absence of external drivers); and
- the ability of a system to invent creative solutions in response to change.

As the figure below suggests (modified from Hahn et al. in press), a social-ecological system consists of three parts: the first concerns the capacity of ecosystems to generate ecosystem services, the second concerns how different management practices influence ecosystem capacity, and the third concerns the underlying institutional capacity of ecosystem management. Signals and feedback from the ecosystems are interpreted by knowledge systems that in turn are fed into, and influenced by, management organizations and institutions.



Resilience in a social-ecological system depends on the capacity of ecosystems as well as social capacity to respond to ecosystem change in a way that sustains and enhances the capacity of ecosystems to generate essential ecosystem services (Folke et al. 2003). "Social capacity" in this context includes organizational capacity (organizations capable of executing responses) and institutional capacity (the rules and social norms underlying these organizations). Social capacity can also be understood as capital defined to include social capital (trust, skills in collaboration and conflict resolution, etc.; see, for example, Pretty 2003); human capital (advancement in different knowledge systems); and cultural capital (beliefs about how people, nature, and society are related, sometimes called a worldview; see Adams et al. 2003; Berkes and Folke 1994; Castro 1984; Contreras 2003; and Gatmaytan 1992).

Resilience is particularly crucial to how people understand vulnerability (both their own and that of their environments). Thus resilience bears directly on how actors shape and design their responses, including the trade-offs that they may decide to incur between complexity and reach of their responses.

The sub-global assessment teams were asked whether the responses observed in their assessments appeared to be effective or not. This was not an easy task: it is widely known that for effective decision-making, political, institutional, economic, social and ecological implications across various domains should be identified and analyzed. Where this is not done adequately, many strengths and weaknesses of responses might not be fully considered by decision-makers. The implementation of the idea of integrated assessment requires extensive resources, because it needs to recognize the multidimensional nature of impacts; it also requires methods that are sensitive to a plurality of perspectives from diverse scientific and other disciplines. Decision-makers are often subjective when judging the success or failure of a response. Along any one dimension, using any particular criterion for assessment, the evaluation process can distinguish between constraints that render a policy option unfeasible, and those considerations that, while important, may be treated as costs associated with the implementation of an option that stakeholders might be willing to bear. (See MA *Policy Responses,* Chapter 3.)

An assessment of responses may be an enormous task; it is worth doing, however, as it becomes a guiding element for decision-makers. Evaluations of the human dimensions of ecological responses are bound to be subjective. Decision-makers must be geared to face the situation where consensus is rare and conflict is in abundance. Important steps that should be taken to limit potential conflict include emphasizing inclusive evaluation processes, so that assessments are not only done by elite decision-makers; maintaining transparency and accountability throughout the assessment process; and ultimately, developing responses that are flexible enough to maintain their effectiveness despite dynamic social and ecological conditions. (See MA *Policy Responses,* Chapter 3.)

In the sub-global assessments, an *effective* response improves the condition of ecosystems services and human well-being (or at least improves one without reducing the other). Acknowledging the difficulty in assessing the effects of responses, the sub-global assessment teams were also asked whether the social capacity to organize effective responses had increased in their assessment areas as a result of a given response. If so, that response was viewed as *promising.* (See Appendix 9.2.) This is consistent with the resilience framework which assumes that social capacity-building is crucial for enhancing ecological capacity to generate ecosystem services.

The fact that responses have been an interest of the sub-global assessment teams may have resulted in some bias toward successful or effective responses. Hence, the selection of responses analyzed should not be viewed as a random sample of "what is going on at the sub-global level." Ideally, each sub-global assessment would have identified responses *and non-responses* to the most pressing conditions and the most important trends and drivers in ecosystems, and assessed the institutional capacity to undertake appropriate responses. Such a rigorous approach was applied to varying extents in the sub-global assessments. Nevertheless, the reported 37 responses offer good insights into the dy-

namics of social-ecological systems in different parts of the world, along with several emerging lessons learned.

As was mentioned earlier, many sub-global assessments are still on-going and it is too early to evaluate the long-term success or failure of the reported responses. Some responses can be interpreted as ineffective in terms of not appearing to reverse or halt current trends in declining ecosystem services. However, these are not necessarily ''bad'' responses; ineffective responses may have more to do with the actors' lack of economic and political power (see discussion below).

9.2 The Sub-global Findings on Responses

9.2.1 The Complexity of Sub-global Responses

Most of the 37 responses were complex. They involved multiple actors initiating and executing actions at many levels of organization, and using a variety of knowledge systems and instruments of action. The complexity of responses seems to cut across all sub-global assessments.

9.2.1.1 Actors

The most common responding actors were governments at national and/or sub-national levels, followed by communities (which include local civil society organizations, leaders, and sometimes local governments). Research institutions and the business sector initiated very few of the responses reported, although they more often became involved in the responses at a later stage. For almost all reported sub-global responses, several actors were involved in the execution/implementation. (See Appendix 9.2.)

Actors have varying roles and capacities to shape and reshape responses. For example, an actor may have developed a good proposal to respond to declining ecosystem services. However, good ideas are not sufficient. The problem that the proposal responds to must be perceived as pressing to the political community, and there must be political momentum and a politician who is able to push and negotiate the proposal through the political process. When these occur, policy windows are opened (Kingdon 1995). (See Box 9.2.)

9.2.1.2 Organizational Levels

A coordinated response that embraces more than one organizational level entails vertical or multilevel collaboration.

Coordination occurs generally when institutional interactions are benign (Young 2002), which may be hard to assess. For instance, in India, forest ecosystem services for decades were managed formally at the sub-national (state) level, except for national parks, which were managed at the national level. When new biodiversity management committees were created after the Biological Diversity Act was passed in 2002, village councils (which are elected bodies at the local community level) suddenly had legal power to co-manage forests. This multilevel institution for forest management may result in eroded legal power at the sub-national (state) level unless the state Forest Departments find new ways to collaborate with the village councils. (See Box 9.3 for this and other examples of sub-global responses with successful multilevel collaboration.)

Multilevel collaboration sometimes involves conflicting priorities. In the Caribbean, the U.N. Resolution on Integrated Management of the Caribbean Sea emphasized co-management of marine resources at the regional level. While this provided a collective framework for management, to date there has been no organized progress on implementing the commitments to, or exploiting the opportunities of, this Resolution. Moreover, the different historical legacies, languages, cultures and traditions, and norms and legislation of the 33 participating countries pose (often serious) constraints on their cooperation (Caribbean Sea).

Western China has succeeded in some responses through integrated government policy. This includes a series of local interventions, in collaboration with local governments, to combat poverty while at the same time halting current de-

BOX 9.2

Taking Advantage of Policy Windows: Sweden KW and South Africa

According to Kingdon (1995), the simultaneous existence of a perceived pressing issue (problem stream), a proposal suggesting a solution (policy stream), and political momentum (political stream) explain political decisions. The policy entrepreneurs perform the function for the system of coupling the previously separate streams. Two forces may open a window: either decision-makers become convinced that a problem is pressing and seek a policy (problem-driven window) or they adopt a theme for their administration and look for problems that may justify change and proposals that support their theme (politically driven window). The window opens because of some factor beyond the realm of the policy entrepreneur but this person/group takes advantage of the opportunity. Different interest groups usually develop certain policies and proposals and then wait for problems to come along to which they can attach their solutions, or they wait for a development in the political stream that favors their proposals.

For Kristianstad Wetlands, Sweden, a policy window was open at the municipal level after the national election in 1988 that highlighted environmental issues. A policy entrepreneur (who became the director of Ecomuseum Kristianstad Wetlands in 1989) had already formulated a proposal based on the vision of an ecosystem approach and managed to generate broad support for this among local stakeholders. A key politician was willing to push the proposal through the decision-making process. Three factors were necessary to enable this response: the existence of a proposal, an open policy window, and a top politician who pushed the proposal through the political process (Olsson et al. 2004b).

The democratic transition in South Africa in 1994 opened a policy window for water management. The new government established a national panel representing all interest groups to craft the National Water Act of 1998. The Act gave priority in the allocation of water to basic human needs and the needs of aquatic ecosystems, and established a framework for the rational allocation of the remainder. This new legislation was based on the principles of equitable benefit-sharing, ecological resilience, and efficiency, and marked a dramatic shift from the previous water legislation that favored the agricultural sector and gave riparian rights to landowners (Bohensky et al. 2004).

BOX 9.3

Bottom-up and Top-down Collaboration: Sweden KW, Laguna Lake Basin, and India Local

A response executed by the public sector may be based on ideas and initiatives from any stakeholder. For instance, in Kristianstad Wetlands, Sweden, the municipal response was sparked by the vision of one key individual and developed into a proposal in collaboration with a few stakeholders across sectors (environment, agriculture, tourism, and university). This proposal was adopted by the municipal executive board and turned into a policy for ecosystem management. The number of stakeholders involved increased during the trust-building and learning process of implementation, resulting in horizontal (multisector) and vertical (multilevel) networks. The latter have been important to attract project funds from the national and EU levels. Thus a bottom-up initiative has resulted in a flexible, cost-effective project organization that has succeeded in applying the ecosystem approach and adaptive co-management to water resources without changing the legal framework (Sweden KW; Hahn et al. in press).

Laguna Lake Basin illustrates successful collaboration through top-down initiatives. The Laguna Lake Development Authority responded to declining water quality by forming River Rehabilitation Councils to address the pollution coming from the lake's 22 tributaries. The councils are composed of people's organizations, environmental groups, industry representatives, and local government units, with the Laguna Lake Development Authority as the facilitating institution. The involvement of civil society has proven to be crucial to resolving major conflicts (for example, industry versus community; fishery versus industry; agriculture versus conversion of land to other uses). The multisectoral nature of the councils has resulted in a sustained clean-up of some tributaries, thereby reducing pollution loading in the lake (Laguna Lake Basin).

India's Biological Diversity Act of 2002 aims to achieve cooperation from the range of resource users through a multiscale management approach. This involves the establishment of biodiversity management committees at the *Panchayat* (village council), municipality, and city corporation levels, to complement the State Biodiversity Board and National Biodiversity Authority. The recognition that critical biodiversity knowledge is also held at the grassroots level is reflected in this decentralized management approach. Effective implementation of the Act will rely on global, national, and local information. For example, the selection and preservation of threatened species requires information on global and national socioeconomic factors, local tenurial arrangements, and site-specific biodiversity. Thus the layered documentation will provide a valuable knowledge base to underpin decision-making at each management level as well as across the multilayered management structure (India Local).

clining trends in several ecosystems. One effective intervention is the Grain for Green Project, in which degraded farmland or slopes are converted back to forests or grasslands. Farmers receive monetary compensation and also benefit from the trees, shrubs, and grass (Western China).

Integrated responses involving stakeholders at several organizational levels are not a goal in themselves; in some cases, a targeted action by a single actor using a single instrument was effective. This is best illustrated by the South African Water Act of 1998, which was an effective response to several conflicts and drivers.

In the Southern Africa local assessment, responses by households and communities were successful in maintaining a diversity of livelihood strategies. However, these households and communities are often unable to deal with the drivers of social and ecological change (such as macroeconomic policies, government inefficiencies, diseases and epidemics, and climate fluctuations). Households and communities often do not have sufficient capacity to involve agencies and other actors at higher organizational levels to address local concerns. Hence responses generally appear insufficient or ineffective in terms of their ability to reverse or halt current trends in declining ecosystem services. These are not necessarily ''bad'' responses but reflect the actors' lack of power or organizational and institutional capacity. One important reason behind the failure of some responses is the lack of collaboration between local and national levels of decision-making. In situations without collaboration, governments may respond to water scarcity, for example, by building a dam, but the benefits may not accrue to local people, who often do not have access to municipal water services and instead must resort to alternative responses such as storing water in individual small, mobile containers. Local people are frequently averse to large dams and other large infrastructure because they take up valuable grazing land, reduce the diversity of options, and often do not benefit people in the immediate vicinity.

The only ineffective response highlighted by a sub-global assessment involving more than one organizational level was the creation of wildlife management areas in Papua New Guinea. In this case, local and national actors had different objectives (not just different priorities) resulting in an *uncoordinated* response. (See Box 9.4.) Hence, a multiplicity of organizational levels does not automatically enhance response effectiveness (discussed at greater length later in this chapter).

9.2.1.3 Knowledge Systems

There tended to be spontaneous and extensive mixing of knowledge systems in the sub-global assessment responses, reflecting ubiquitous multi-actor collaboration. Scientific knowledge was used to craft 34 of the 37 selected responses; where scientific knowledge was not used, responses appear to have been ineffective. (See Appendix 9.2.) The ineffectiveness of these responses may, however, be attributable to other factors, such as power imbalance and conflicting interests between local people and central authorities, rather than lack of adequate knowledge. Local ecological knowledge was used in 25 responses but never as the sole source of knowledge. Traditional/indigenous knowledge was used in 13 responses but never together with scientific knowledge unless local knowledge was also involved. This suggests that local ecological knowledge might actually serve as a bridge between scientific and indigenous knowledge. Ten of the selected responses used a combination of all three types of knowledge.

As was the case with multiple organizational levels, the multiplicity of knowledge systems did not automatically enhance the effectiveness of a response. For instance, in San Pedro de Atacama, an area of indigenous development had been established, in which government departments and

BOX 9.4

Wildlife Management Areas in Papua New Guinea: A Colonial Response with Unexpected Results

Wildlife management areas were established in Papua New Guinea under legislation passed at the end of the colonial period to mitigate the threat to biodiversity that was thought to have arisen as a result of the acquisition of shotguns by local villagers. The legislation allows a local community to have a portion of its territory designated as a wildlife management area and then to establish a management committee that would make and enforce its own rules to regulate hunting activities within the protected area. This is still the only effective legal instrument in Papua New Guinea for the protection of biological diversity in areas held under customary ownership.

In practice, local communities have commonly used the WMA designation as a device to register claims to their traditional territorial domains against the claims of neighboring groups of customary landowners. Only in a minority of cases have they been persuaded by nongovernmental organizations to adopt this measure as a response to the anticipated loss of biological diversity. Even where WMAs are providing biodiversity protection, there is nothing in policy or legislation to prevent government agencies from negotiating with local landowners to include the WMA within an area allocated for resource development that might threaten biodiversity. Local landowners will commonly take this development option because it enables them to establish another kind of legal claim to customary ownership of their resources, as well as to secure a share of the resource rent generated by the development process.

In the meantime, the original rationale for the legislation creating wildlife management has largely disappeared, because the cost of buying shotguns and cartridges now exceeds the monetary or subsistence benefit that can be derived from their use.

BOX 9.5

Public and Private Sector Actions: San Pedro de Atacama

The Antofagasta region in northern Chile has low social capital, with a poor associative capability and a weak sense of belonging among its people. However, the municipality of San Pedro de Atacama, presents a different situation, with strong associative and organizational capability and an unprecedented opportunity to respond to challenges raised by ecosystem change.

The ADI ("*área de desarrollo indígena"* or area of indigenous development) is the mechanism used to coordinate *public sector* decisions and priorities. It seeks to bring national scale institutions in touch with specific local situations. Here, public sector bodies set out their priorities and decisions with the Atacameño community, and agree on priorities or coordinated efforts in order to achieve certain objectives. Although this initiative has only been in effect since 2002, it has contributed to reducing communities' distrust of the public sector. Unfortunately, ecosystem changes have not yet become a focus for the ADI's work issues and objectives.

All the *private sector* institutions and stakeholders with influence in the area, such as mining and tourism companies, are excluded from the ADI. In the community this has generated the perception of two separate and opposing blocs. To overcome this division, the sub-global assessment team set up an advisory committee (*Grupo Asesor*) that includes the private sector. The advisory committee provided an arena for dialogue and decision-making. Area leaders and key sector representatives for the Salar de Atacama's ecosystem were invited to participate.

The advisory committee was made up of 16 representatives from different sectors and interest groups, and held regular meetings. Following its first meeting in October 2003, participants stated that this was the first time public and private sector bodies and community representatives had sat down together to discuss the ecosystem and local development. Capacity-building was reinforced through scenario workshops undertaken in late 2004.

representatives from local indigenous communities might work together toward developing the area. Multiple initiatives have been undertaken to recover the local communities' traditions and indigenous knowledge on such matters as health, education, and community development. However, these have yet to be incorporated into the ADI's formal decision-making processes, where discourse is still in the language of science and bureaucracy. Still, the institutional capacity for responses has increased with the ADI and the new advisory committee for that sub-global assessment. (See Box 9.5.)

9.2.1.4 Instruments of Action

The most common instruments of action employed in the 37 selected responses were organizational devices, that is, the formation of new entities for collaboration among actors (27). This is followed by statutory/legal and economic devices (21), and social, behavioral, and cognitive change (20). Direct interventions and technological innovation or dissemination were not frequently an important part of the reported sub-global responses; apparently the assessment teams regarded collaboration and other institutional innovations, initiated by new organizations, as more important.

Organizational devices are formal and informal measures to organize multi-actor collaboration. For most responses, this involved the formation of new organizations with specific management responsibilities (for example, the River Rehabilitation Councils in the Philippines) or devolution of management authority (for example, biodiversity management committees in India Local and the co-management arrangements in St. Lucia, Caribbean Sea; see Box 9.6). Some responses rely on informal measures (for example, Sweden KW), which illustrates how collaborative learning in social networks without any formal power to set or enforce rules can solve conflicts and pave the way for effective responses. The joint forest management organizations in India Local started as an informal collaboration but later acquired statutory status. These collaborations between the local and sub-national/national levels provide conflict resolution arenas for different stakeholders, even if they do not always have formal power.

The *legal and economic devices* were in most cases national policies or laws. Economic incentives were rarely reported by the sub-global assessments. Possible reasons for this are discussed later in this chapter.

9.2.2 The Spatial Reach and Effectiveness of Sub-global Responses

Most sub-global responses did not address all drivers of ecosystem change or all impacts on human well-being. They

BOX 9.6

Government–Community Co-management of a Sea Urchin Fishery: St. Lucia, Caribbean Sea

Since the 1950s, the white-spined sea urchin *Tripneustes ventricosus* has been part of locally important open access fisheries in the Caribbean island of St Lucia. The sea urchins are harvested for their edible roe which is eaten roasted, but during the 1970s and 1980s, the prepared shells were also sold as ornaments. In the early 1980s, severe declines in sea urchin stocks led to the voluntary closure of the fishery by the community and government. In 1984, new legislation prohibited the "disturbance of sea urchins" without written permission from the Chief Fisheries Officer. The fishery was formally closed by the Department of Fisheries in 1987, with the ban remaining in place until 1990.

In order to determine the conditions for the recovery of the stocks and the management of the harvest, a monitoring program was carried out from 1987 to 1989 to assess the abundance, growth, and recruitment of sea urchin eggs. In 1989, discussions began between the Department of Fisheries and the sea urchin harvesters on the feasibility of implementing a co-management arrangement and resuming the harvest under controlled conditions. The fishery was then re-opened with provisions for the harvesters to assume co-management responsibilities.

These responsibilities included observing a minimum size limit for harvesting and reporting when the large size classes were depleted so that the harvest could be closed. Other management measures introduced over time were identification cards for harvesters, harvesting licenses, export licenses, and a maximum permitted selling price. In 1993, the Department of Fisheries also issued notices, requiring harvesters to form groups and select individuals to represent them in licensing negotiations. These groups were required to participate in monitoring the status of stocks before licenses would be issued, with no licenses being issued if stocks were lower than previous years. A further requirement imposed was for sea urchin egg cleaners to obtain licenses. According to Smith and Koester (2001), discussions with local residents in May 2000 indicated that the co-management system was having its intended effect.

addressed only direct drivers that could be modified by the responding actors within their immediate landscapes. Hence, the responses tended to be direct, deliberate, and practical in purpose and design.

The responses gravitated around issues that can be attended to immediately and locally (such as land use, cropping, pollution, social and ecological conflicts, planning, and regulations). None focused on exogenous drivers of ecosystem change such as climate change, population growth, urbanization, external trade pressures, or technological and political changes. These drivers are recognized as concerns in a number of sub-global assessments (see Chapter 7 for a full treatment of drivers), and some responses could be seen to address some aspects of the local manifestations of these drivers. For instance, the São Paulo Green Belt can be seen as both a response to local climate change (lowering temperature) and a local response to global climate change (carbon sequestration). But no response, by itself, was focused on addressing these drivers directly or exclusively. It seems that most of sub-global actors were reluctant to invest efforts in trying to control what appeared to them to be beyond their control. While some responses attempted to reach beyond their immediate locales (for example, involving the United Nations in the case of the Caribbean Sea, and the establishment of a regional organization in the Tropical Forest Margins assessment), most were limited to only what was do-able or modifiable by the responding actors within their immediate areas.

Indeed, drivers are recognizably multiscale, and they are often interpreted according to the scale from which they are perceived by actors. (See Chapter 4.) For instance, urbanization can appear to be an indirect driver at the village level in the India Local assessment, but a direct driver at the national or regional levels in other sites (for example, Sweden SU). For actors at these different scales, urbanization can be addressed by either better village planning or by changes in economic policy (discussed later in this chapter).

The effectiveness of the responses, too, was apparently viewed by local actors (and the assessment teams) in terms of their impact on ecosystem changes and human well-being at specific scales. That is, their judgments on how much a response was affecting ecological conditions and social capacities were based on what they saw within the boundaries of their sphere and scale of interest. For instance, actors involved in biodiversity conservation in Portugal and in Kristianstad Wetlands, Sweden, shaped actions that acknowledge the European Union agricultural subsidy system, but did not work with the subsidy system itself.

9.2.3 The Dynamic Nature of Responses

Most responses in the sub-global assessments involved actors from several sectors and organizational levels, using multiple knowledge systems and instruments to implement responses. Collaboration among stakeholders had the effect of bringing together an array of actions, and it is sometimes hard to know whether these actions should be regarded as a single, composite, or several interrelated responses. Each of these actions has the potential to complement or limit other actions, and thus either strengthens the response, inhibits it, or evolves into an entirely new response. (See Box 9.7.)

9.2.4 The Effectiveness of Multilevel Responses

Of the 37 selected responses analyzed in this chapter, seven can be interpreted as ineffective, in that they do appear to reverse or halt current trends in declining ecosystem services. (See Appendix 9.2.) As noted, these are not necessarily "bad" responses, but rather reflect the actors' lack of power or organizational and institutional capacity. These seven ineffective responses occur in PNG, SAfMA Livelihoods, Bajo Chirripó, Sinai, Northern Range, and Sweden SU. Six of these ineffective responses involved only one organizational level, often the local level, where actors at the local level were in conflict with (or at least enjoyed no financial, institutional, or political support from) actors at the national level. Hence, ineffective responses may be attributed to the lack of multilevel collaboration; this finding is supported in a review by Pretty (2003).

BOX 9.7

Aggregated Responses: São Paulo and Sweden SU

The São Paulo and Stockholm sub-global assessments provide good examples of aggregated responses. Urbanization and declining green spaces prompted certain actors to initiate actions to mitigate these trends. In both cases, the initial actors expanded their collaboration with other actors at different levels of organization (international, municipal, and other organizations in the case of São Paulo; the national government, three municipalities, and several NGOs in the case of Stockholm), which prompted multiple actions by actors other than those who initiated the response. On the one hand, many of these actions can be seen as a composite response to the same situation. On the other hand, the actions can be regarded as a sequence of different responses where one response feeds into another.

In the case of São Paulo, the creation of a UNESCO Biosphere Reserve, a process originated at the grassroots level, was used to initiate a multisector effort to develop integrated environmental management strategies focusing on the entire São Paulo Green Belt. Many different activities have been initiated, related to forestry, sustainable agriculture, ecotourism, public awareness, social and community projects, participatory management, and the sub-global assessment initiative itself. These are intended to complement each other in a single integrated approach to managing the area (São Paulo).

In the case of Stockholm, the initial actions by environmental organizations to control the loss of green spaces engendered other actions that then evolved into different responses, one by the national government (to establish the first National Urban Park in the world), others by the County Administrative Board, and yet others by citizen groups that have now organized to advocate controls on urbanization. The National Urban Park now requires three municipal governments within Stockholm County to perform a diverse range of tasks related to developing and maintaining the park (Sweden SU).

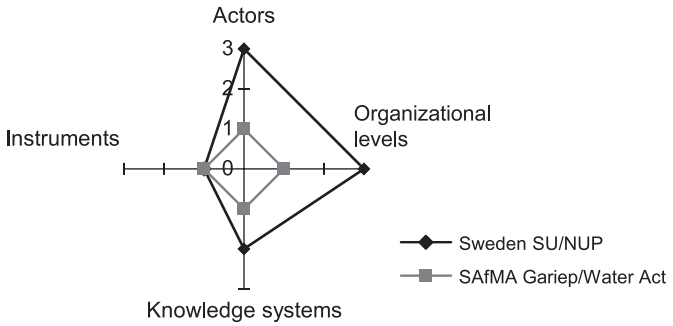


Figure 9.2. Responses Using National Legislation as an Instrument May Be Different in Features and Complexity. The National Urban Park (NUP) and other forms of protected areas in Stockholm Urban assessment (Sweden SU) resulted from initiatives by several actors at different organizational levels using different knowledge systems. The SAfMA Gariep Basin/South African Water Act of 1998 involved a panel representing different stakeholders (see Box 9.2), but the process was initiated and executed by the government; hence it can be regarded a single-actor response. Both responses were effective, which illustrates that there is no simple relationship between the complexity of a response, as defined in this chapter, and its effectiveness. Both responses appeared to have made appropriate trade-offs, for their specific contexts, between a more complex response entailing extra cost, and cost-effectiveness.

However, multiple organizational levels need not necessarily be involved for responses to be effective. Figure 9.2 compares two effective responses; although both use national legislation as a policy instrument, the complexity (number of actors, organizational levels, and knowledge systems) differs markedly. Nine of the 30 apparently effective or promising responses involved only one organizational level, usually the local level, but in these cases the actors were not in conflict with actors at other organizational levels, and they had sufficient institutional and organizational capacity to carry out the response by themselves (for example, the Stakeholders against Destruction for Toco, Trinidad). Hence, even if a response is done at only one organizational level, good cross-level relations would be valuable.

The remaining 21 apparently effective or promising responses involved coordination among several organizational levels. Such ''vertical collaboration'' was an important element in the success of all 21 responses, according to the sub-global assessment teams. The important factor here is coordination; mere involvement of actors at several organizational levels does not in itself increase the effectiveness of a response, as discussed below. The active involvement of several actors may not always be cost-effective, considering the trade-offs and opportunity costs; the resources used to involve more actors may mean forgone opportunities to use the same resources for other purposes, such as undertaking other responses or increasing the reach of a given response.

9.3 Impacts and Effectiveness: Lessons Learned

Several patterns emerge concerning how the complexity and reach of responses are related to impacts and effectiveness.

9.3.1 Collaboration: The Interplay of Informal and Formal Institutions

From the 37 selected responses, the pattern that emerged suggests that the effectiveness of a response is correlated to the collaboration of a variety of actors involved in its execution. There appear to be at least three reasons for this pattern.

First, horizontal (multisector) collaboration ensures that multiple objectives (ecological, social, cultural, economic) are addressed in an integrative fashion (Wondolleck and Yaffee 2000). This involves public agencies as well as nongovernmental organizations. Compartmentalized decision-making bodies typically impede multisector collaboration. In urban Stockholm, for example, the county administrative board and national authorities are divided across different sectors, resulting in inconsistent policy proposals (conservation versus development), while environmental NGOs do not collaborate with the business sector to resolve conflicting objectives (Sweden SU). Hence, responses to halt urban sprawl have not been effective. Similarly, the Northern Range Hillside Development Policy in Trinidad was a good plan, but it was impaired by lack of collaboration and an

inadequate administrative structure in which well-defined enforcement mechanisms were not fully integrated (Northern Range).

Second, vertical (multilevel) collaboration increases the probability that responses have a positive impact on the social and ecological drivers of ecosystem change. To the extent that these drivers occur at a continuum of social and ecological scales, responses may be more effective if they involve decision-makers (and action-takers) at multiple organizational levels. Responses, to be effective, often need to address a range of drivers and interactions of social and ecological systems, to match the reach and interactions of those drivers. The existence of several actors, at various organizational levels, managing the same natural resource, results in a redundancy in governance. This is generally criticized in policy analysis, although it has been defended in the management of complex adaptive systems like ecosystems (Low et al. 2003), which require institutional flexibility. An array of institutions at different organizational levels enhances the diversity of response options (Hahn et al. in press). This has been referred to as scale-matching (Lee 1993), institutional fit (Folke et al. 1998; Brown 2003), or multilayered or polycentric governance (Ostrom 1998; McGinnis 2000).

Third, public participation is important for effective decision-making and execution of responses. Pretty (1995) discusses two fundamental reasons for public participation in development projects: (1) as a means to increase efficiency (if people are involved in a project, they are more likely to support it), and (2) because it is a fundamental right that relates to empowerment. To this could be added another reason, namely that the knowledge base can be significantly broadened by acknowledging the local, traditional, and indigenous knowledge of different stakeholders. Each knowledge system contains specific ecological, social, cultural, economic and political knowledge that influences the design of a response. It has been suggested that responses to ecosystem change can be enhanced if a diversity of knowledge systems is acknowledged (Gadgil et al. 1993; Dahlberg 2000). In the case of scientific knowledge, it often needs to be interpreted and contextualized by actors who know the local conditions, and be synthesized with other kinds of knowledge systems (Folke et al. 2003). This is well-illustrated by the responses in Sweden KW (Olsson et al. 2004b).

People who depend on ecosystem services for their livelihoods often accumulate ecological knowledge that external researchers lack (Tengö and Hammer 2003). Through adaptive management, including close monitoring of a diverse set of ecological variables, they are able to observe and understand early signals of ecosystem change, and to distinguish this from natural variability. Hence, community-based natural resource management (for example, devolution of management authority to co-management arrangements as in the Caribbean Sea) has implications for democracy (empowerment) but also for resilience in social-ecological systems. (See Chapter 11.)

The existence of several actors, at various organizational levels, managing the same natural resource, does not result in constructive collaboration and effective responses unless the institutional interaction is benign (Young 2002). Sometimes the overlaps in management responsibilities result in conflicts over management objectives and practices. This impedes collaboration and effective execution of responses, as illustrated by the São Paulo and Sweden SU assessments. Hence, even if the technical and institutional *resources* to respond appear to be high, the social *capacity* to coordinate various actors and policy instruments can be lacking.

Overlaps among sectors are unavoidable. For instance, projects driven by economic motives often have unintended ecological effects. Within the ecological sector, the legal competencies of institutions at different levels (national, district, community) generally overlap to some extent. Reducing overlaps in management responsibilities could be a solution to conflicts, but can also result in compartmentalization and reduction in the diversity of knowledge systems and of responses. A more fruitful approach, as suggested by the findings of the sub-global assessments, is to make an effort at improving collaboration: of the 22 sub-global responses where several actors at different organizational levels were involved in the execution of responses, 21 exhibited constructive collaboration resulting in effective, or at least promising, responses.

The interplay among various instruments of action is another theme in several sub-global responses. One conclusion is that the combination of ''hard'' formal institutions (legislation, economic incentives, and subordinate rules) and ''soft'' instruments (social, behavioral, and cognitive change, and also the formation of non-statutory organizations) is of particular interest. Learning and experimentation thrive in informal settings, but formal institutions define power relations when negotiation is needed to solve conflicts (Hahn 2000). The interaction between learning and collaboration in informal networks on the one hand, and formal decision-making and enforcement on the other, appears to be a crucial challenge facing several sub-global responses.

Navigating these social-ecological systems requires an atmosphere of high trust (Ostrom et al. 2002; Berkes et al. 2003; Pretty 2003). Examples of the importance of trust-building can be found in San Pedro de Atacama (where an advisory committee brought together public and private interests); Caribbean Sea (the Department of Fisheries and sea urchin harvesters in St. Lucia reached an agreement on new institutions); India Local (Joint Forest Management is important for achieving desired outcomes); Portugal (actors with diverging interests are developing a certification system); and Sweden KW (a range of effective trust-building responses).

9.3.2 ''Bridging Organizations'' Facilitate Multiscale Collaboration

In half of the selected 37 responses, governments at national and/or sub-national levels and local communities collaborated in the execution of the response. This is typically the kind of collaboration that is missing in ineffective responses and highlights the importance of national governments and

"bridging organizations." A bridging organization provides an arena for trust-building, sense-making, identification of common interests, learning, vertical and/or horizontal collaboration, and conflict resolution (Folke et al. 2005). Bridging organizations create the space for innovative institutions. Bridging organizations differ from "boundary organizations," which synthesize and translate scientific knowledge to make such knowledge relevant for policy-making. (See the Glossary for further clarification.)

In some sub-global assessments (SAfMA Livelihoods, Bajo Chirripó, Sinai), local people are politically and economically marginalized and thus lack the organizational and institutional capacity to initiate collaboration. For instance, in the Southern Africa local assessments, community members are noted to have a good deal of social capital, but because they lack technical skills or access to markets, they are unable to convert this social capital into action (although there are some exceptions). The same applies to national-level actors referred to in SAfMA Livelihoods: good policies are in place but the human resources to do the job are scarce, and corruption often impedes capacities.

Vertical collaboration requires that actors at different organizational levels are free to initiate collaboration. In the Joint Forest Management of India Local, bottom-up initiatives have worked better than top-down initiatives. (See Chapter 11.) The relationship between rights and freedom is determined by formal institutions (laws and rules), but also by informal institutions (social norms and conventions). Most sub-global responses involve local level actions and they suggest a clear pattern: democratic and representative participation of local communities correlates strongly with effective responses. In some cases, although participation was acknowledged as important, effective participation did not occur because the enabling formal institutions were not in place or not enforced (SAfMA Livelihoods and Bajo Chirripó). Some local communities considered the concept of participation in this case as lip service rather than a genuine effort. In Sweden SU, there is great potential for collaboration because the institutional resources are in place; however, no actor has managed to take sufficient leadership to form a bridging organization or to perform the functions of such an organization.

9.3.2.1 Under What Circumstances Does Collaboration Take Place?

Collaboration takes place when key stakeholders realize that they cannot reach their goals in isolation from other stakeholders (Wondolleck and Yaffee 2000). The sub-global assessments provide several examples of this pattern:

- The advisory committee in San Pedro de Atacama was a horizontal collaboration of actors across sectors, and the assessment team functioned as a bridging organization, leading the actors to collaborate on ecosystem issues for the first time.
- In Sweden KW, the organization Ecomuseum Kristianstad Wetlands is a textbook example of a bridging organization. EKW has transformed local conflicts between nature conservation and economic development into win-win situations, by offering an arena for trust-building, collaborative learning, conflict resolution, and adaptive co-management (an adaptive management system involving several actors at more than one organizational level; see Olsson et al. 2004a).
- In the Caribbean Sea assessment, an NGO has functioned as a bridging organization for policy-makers in St. Lucia and local communities. Mangroves have become marine reserve areas, and reforestation projects are meeting local demand for fuelwood. In the Tropical Forest Margins assessment, land and tree tenure reform in Indonesia is facilitated by the Alternatives to Slash-and-Burn program, which functions more and more like a bridging organization (the first Tropical Forest Margin response was to establish ASB). This tenure reform was the result of several years of dialogue and consensus-building involving research institutes, NGOs, local government offices, and the Krui community.
- In the Philippines, the Laguna Lake Development Authority has been responding to ecosystem change for several years, but it was only with the formation of River Rehabilitation Councils that a comprehensive and effective response could be put in place. The scientific community played an important role in this case.

Indeed, the scientific community may function like an NGO in offering services intended to benefit communities and constituencies that are often left unserved by the formal institutions of the state. Similar examples are presented in the India Local, Portugal, and Tropical Forest Margins assessments.

9.3.2.2 Bridging Organizations and Adaptive Capacity

Eight responses that were initiated or coordinated by bridging organizations (that is, the advisory committee in San Pedro de Atacama, the NGO response in the Caribbean Sea, two Sweden KW responses, two Laguna Lake Basin responses, the Portugal ExtEnSity project, and Tropical Forest Margin tenure reform) exhibit a similar pattern in features: a multitude of actors, several organizational levels, a diversity of knowledge systems, and an emphasis on institutional innovation and social learning. (See Figure 9.3.) These responses illustrate the adaptive capacity of sub-global actors to mitigate the declining conditions and trends in ecosystem services observed at an aggregated level. Similar organizational dynamics probably underlie several other responses, but a local, fine-grain analysis would be needed to discover them. (See Chapter 11.) This finding supports neither centralization nor decentralization, but rather polycentric (multilayered) institutions that enhance the adaptive capacity and effectiveness of sub-global responses. In order to develop context-specific responses that do address the full range of most relevant drivers, sub-global actors need "enabling legislation" from higher organizational levels (Olsson et al. 2004a).

The previously mentioned examples of multisector and/or multilevel collaboration appear to have resulted in effective responses. Trust-building processes appear to have underpinned these instances of collaboration. Investment in

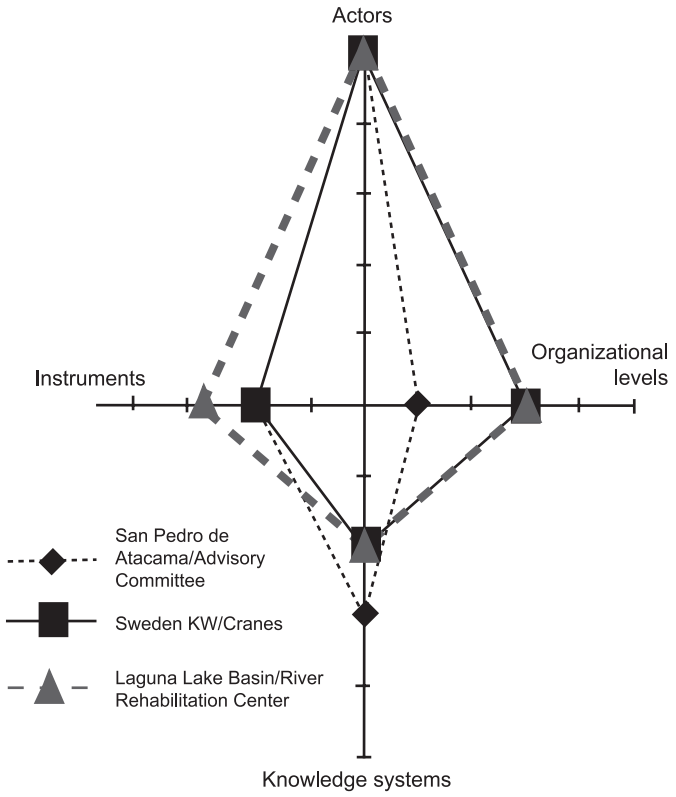


Figure 9.3. Four Features of Responses for Three Sub-global Responses Where Bridging Organizations Played a Major Role. The similarities in features are striking, although the contexts of the responses are very different. Bridging organizations bring different actors together. In the Advisory Committee of San Pedro de Atacama, Chile, only local actors were involved, while the other responses included actors at three organizational levels.

trust-building can be viewed as a transaction cost that ought to be minimized according to conventional economic theory (for example, North 1990). However, recent research on ecosystem management (for example, Olsson et al. 2004a; Scheffer et al. 2002) suggests that investment in trust-building is crucial for mobilizing institutional and organizational capacity to make responses. The leadership and facilitation offered by bridging organizations (or key persons where no such organizations exists) is instrumental, as is the synthesis and mobilization of different knowledge systems (Olsson et al. 2004b).

9.3.3 Economic and Social Incentives

Market-based instruments and other economic incentives are mostly absent in the responses reported by the sub-global assessments (the privatization of wildlife mentioned in the SAfMA Regional assessment and the response to forest fires in Portugal are two exceptions). To some extent this is because about half the sub-global responses were crafted at local or sub-national levels, while economic incentives are generally crafted at national, regional, or global levels because the greater breadth of legitimization and implementation requires higher level policy action. For instance, the integrated responses assessed in Western China included an array of policies but no economic incentives.

In general, the absence of reported economic incentives in the sub-global assessments can be interpreted in two, equally plausible, ways.

The first interpretation is that economic incentives do play an important role in the reported and non-reported responses, but the sub-global assessment teams emphasized other types of responses that are more directly within the scope of local actors to initiate and implement. Changes in the institutional arrangements that indirectly provide new economic incentives may be regarded as drivers rather than responses. One example is the EU Common Agricultural Policy, which is extremely important for providing incentives and disincentives for nature conservation and landscape management. This would have a profound effect on agriculture-related responses in Sweden KW and Portugal, but the CAP has been regarded as a driver in these particular assessments. (See Chapter 7.)

Economic incentives provide an institutional framework in which individual actors craft their responses. ''Bad'' (perverse) incentives make it more difficult for local actors to collaborate and work out ''good'' responses that enhance the capacity of ecosystems to generate valuable services. For instance, irrigation subsidies have a profound effect on relative prices and hence water allocation. Surprisingly, none of the sub-global assessments reported on this kind of incentive.

The second interpretation is that economic incentives are not as important to ecosystem management as values and attitudes at local levels. The mere existence of a policy for conserving biodiversity, supported by some subsidies, may not in itself result in effective responses. Instead, *social, behavioral, and cognitive change* appear to be important to understanding the extent to which people respond to economic incentives. Changes in values and attitudes evolve through public awareness and education. Furthermore, values and attitudes can change depending on various internal and external forces including environmental change, natural disasters, education, technological advancement, religion, crime, or war. According to Sen (1995, p. 18), ''many of the more exacting problems of the contemporary world—ranging from famine prevention to environmental preservation—actually call for value formation through public discussion.'' Several sub-global responses emphasized similar issues; for example, the areas of indigenous development and the advisory committee in San Pedro de Atacama were reported to be based on collaborative learning and value formation. The Northern Range civic response at Toco (Trinidad) and India Urban assessments both provide examples of actors formulating visions for improved natural resource management.

Indeed, changes that affect social norms—including values, worldview, vision, and commitment—may be more important as drivers of social change than economic incentives, which only affect cost-minimizing behavior. Without changes in social norms, people often revert to old ways when economic incentives end or regulations are no longer enforced (Pretty 2003). Thus to the extent that conflicting worldviews (assumptions about the relationships between humans, nature, and society) do underlie and explain con-

flicts over natural resource management (Adams et al. 2003), it seems reasonable to address social norms and value formation in assessments of responses. Measures that reduce non-monetary transaction costs for individuals to adopt ''good'' responses can be regarded as ''social incentives.'' Bridging organizations are important to provide these social incentives by rewarding collaboration, learning, reevaluation of preferences, and conflict resolution.

Several sub-global responses involved leadership that provides social incentives to undertake deeper changes in values. Examples include the advisory committee in San Pedro de Atacama; the certification system in Portugal; the range of responses in Sweden KW; land tenure reform in Tropical Forest Margins; and the land use plan change in India Urban. These responses carry elements of *community visioning,* which is a community-wide process with the aim of ''enhancing society's ability to solve problems and resolve conflicts'' (Dukes 1996). Discovering such social processes, which are going on all over the world, requires assessments that include the local level.

Economic incentives are an important part of an enabling institutional framework for responses but social norms and incentives are also important to assess to achieve a fuller understanding of responses. The facilitation, leadership, and social incentives provided by bridging organizations (or key persons in communities) appear to be essential for capacity-building, which in turn enhances opportunities for crafting effective responses today and in the future.

9.3.4 The Reach of Sub-global Responses

The reach of a response across places and time (that is, the spatial and temporal scales of a response) appears to play a critical role in shaping and reshaping the linkages between ecosystem services and human well-being. It affects the choice and success of the combination of responses that are deployed to address different ecosystem changes and their impacts on human well-being.

9.3.4.1 The Reach of a Response across Places

The multiplicity and diversity of actors, organizational levels, knowledge systems, and instruments of action involved in most sub-global responses seem linked to their frequently crossing community (or district, national or regional) boundaries. This also appears to be related to the tendency of many actors initiating a response to match their actions to the geographic reach of the drivers and interactions they seek to address. It seems likely that the tendency of responses to expand across actors and levels of organization may consequently entail movements across space, so the response will actually proceed to involve more actors located in many more places. One example is the impact of upland deforestation causing disruption in watershed functions for downstream stakeholders (see the Tropical Forest Margins assessment). The effectiveness of the responses to deal with this problem will depend on the extent that complementary efforts are undertaken across all places where the drivers have an effect, by all actors in various levels of organizations that may be located in many different places.

If the spatial reach of the drivers and responses vary, then there might be a need for legal and economic interventions which would need to be negotiated by different administrative parties overseeing the management of the ecosystem, to ensure that decisions formulated are efficient and equitable, across all places and scales of organization of the actors involved.

All SAfMA Regional responses and the Portuguese response to forest fires appear to be good examples of using economic incentives as part of a response to complex cross-scale problems. In the more local sub-global assessments, however, organizational devices focusing on collaboration were more common, because these were at the disposal of local decision-makers. This suggests a relationship between the spatial reach of a response and the choice of instrument: organizational devices are very common at local settings while economic incentives are more often used as responses at the national/regional level. Interestingly, the privatization of wildlife and the transboundary water co-management institution described in the SAfMA Regional assessment combine legal and economic devices with organizational devices.

9.3.4.2 The Temporal Reach of a Response

Changes in ecosystems and their corresponding services can occur over a range of time horizons. Losses in provisioning services occur in a relatively shorter time span (''fast variables'') than losses in the regulating and supporting services (''slow variables'').

Temporal properties can influence the type and success of a response. The main factor that underlies the temporal dimension is uncertainty. If the loss in ecosystem service and/or the intensity and breadth of its impact on human well-being is uncertain or unclear, but expected to occur within a short time span, then perhaps a hybrid of regulatory and legal interventions (for example, marine reserves and other prohibitions) might work relatively well, perhaps much more so than economic and market-based incentives that seek to alter long-term behavior.

However, if there is uncertainty but the impacts are expected to occur only in the distant future (for example, in the case of biodiversity decline and the establishment of biodiversity management committees described in the India Local assessment), then perhaps regulations may be best combined with economic and market-based incentives for a response to work well.

It seems that the longer the time scale of an ecosystem change, the higher will be the degree of the uncertainty of its impacts on human well-being; when this occurs, the actors can be less certain about what combination of responses to utilize. Investments in trust-building, learning, collaboration, and conflict resolution, referred to previously as ''social incentives,'' may be of particular importance for longer time scales. Unlike economic incentives, the effects of social incentives continue after the policy (for example, a subsidy scheme) has ceased. The different time spans of effects make the analysis of trade-offs between different instruments of action more difficult.

9.3.4.3 The Combined Effects of Time and Space

The responses described in the sub-global assessments are apparently linked to the unique conditions of ecosystem services across places and time.

This linkage is corroborated by lessons from elsewhere. For example, dryland ecosystems have been observed to be in constant transition (in climatic conditions, production systems, social institutions, and demography; see Mortimore et al. 1998) so that a fundamental problem for their management is that there are often direct trade-offs that need to be accepted between their provisioning services and their regulating, cultural, or supporting services. These trade-offs occur across time and space, and across actors and stakeholders and their levels of organization. In the case of the upstream dams and drainage schemes in the Tigris-Euphrates river system, provisioning services (such as fresh water and food production) have increased, but at the expense of the Mesopotamian marshlands, which have decreased in area by 90% during the past quarter century (UNEP 2002). The degradation of the marshlands over both space and time has led to loss of habitat for native plants and animal communities as well as many species of migratory birds, mammals, and fish, and the displacement of indigenous peoples, the Marsh Arabs. In cases such as this, the temporal, spatial, and social dimensions of the responses all interact to address the same aspects of the changed (and changing) services offered by ecosystems.

9.3.5 Synergy and Coherence

The synergy of responses must reflect the synergy of ecosystem changes. The sub-global assessments show a high degree of synergy among various ecosystem services. (See Chapter 3.) Unsustainable use of provisioning services (such excessive biomass harvesting) may impair the productivity of regulating and supporting services (such as water and nutrient cycling; see the Tropical Forest Margins assessment). This, in turn, might negatively affect the ability of the ecosystem to continue to provide provisioning services in the long run. The loss in regulating services may also have greater effects on human well-being in the long-run when sensitive lands (like catchment headwaters, shallow soils, steeply sloping lands, and landscape sink areas such as wetlands and riverine buffer areas) are subjected to unsustainable cropping or grazing practices. The interdependent nature of ecosystem services, and the impacts that different ecosystem services have on human well-being, have often not been taken into account in management and policy decisions relating to sub-global responses.

This synergy implies that responses to changing conditions of ecosystem services must have the same interdependent and coherent dimensions as the drivers, services, and impacts that they address. The institutional context of an ecosystem service may differ across locales, and what might appear to be a coherent response in one locale, may not be so in another (also called scale-matching and polycentric governance). Indeed, shortfalls in the interdependence and coherence of responses might explain, to some degree, the difficulty of crafting responses that fully address the range of direct and indirect drivers, as these were described in all the sub-global assessments.

9.3.6 Technology and the MA Conceptual Framework

Technology has been posited by many as the answer to several ecosystem problems that we face today. The sub-global assessments as a whole provide few examples of ''technical fix'' responses. Where technological devices were mentioned (for example, by the Alternatives to Slash-and-Burn program in the Tropical Forest Margins assessment, or technological devices for the Barbados Coastal Zone in the Caribbean Sea assessment), these were explicitly adapted to the social–institutional context. This suggests that direct interventions, and technological innovations and dissemination, can only be assessed within a given institutional framework. Indeed, this applies to all responses; the sub-global assessments do not offer any blueprint for which types of responses are to be recommended. However, they do offer many insights into how to think about and organize responses.

In the MA conceptual framework, human well-being is the ultimate goal, and responses are defined as actions addressing ecosystem change, which in turn affect human well-being. However, some sub-global responses (notably in the San Pedro de Atacama assessment and also Sweden KW and Bajo Chirripó) addressed local social dynamics and conflict resolution, which *directly* enhance human well-being. This in turn increases the capacity to respond to ecosystem change. Indeed, this is more consistent with the literature on community-based natural resource management (for example, Hoff 1998) than the MA conceptual framework.

9.4 Lessons Learned for Future Assessments

The sub-global assessments, because they are still ongoing, can be expected to reveal many more aspects about the nature of responses. Several interesting patterns and lessons learned have already emerged from the 37 responses reported from 18 sub-global assessments. However, some pertinent issues have yet to be assessed and may be further addressed in future assessments:

- *The strategies of actors to identify and select responses.* The rational strategies pursued by actors when they accept trade-offs among different types of responses need to be explored further. They might focus on responses that give them the most desired results (in terms of conditions of ecosystem services and human well-being) for every unit of effort they exert; they might focus on features of a response that are likely to have the greatest effect on a driver, but which will command the fewest resources (social, political, financial, economic, and technological) from them; or they might be pragmatic in their choices, focusing on policy instruments within their immediate reach. If the latter is true, future assessments could focus on path dependency and institutional capacities of the regions that are assessed.

- *Actors' investments in responses*. The deployment of actors' investments in different responses or on different features of a response appears to be related to the robustness of their existing institutions and the resilience of their social-ecological settings. If so, future assessments need to employ a more coherent and rigorous approach to analyzing responses. Ideally, each individual assessment should identify responses *and non-responses* to the most pressing conditions and the most important trends and drivers, and assess the institutional capacity of the actors to make the appropriate responses.
- *Adaptive capacities of actors*. The sub-global assessments tend to emphasize the adaptive capacity of sub-global actors to mitigate threatening conditions, trends, and drivers at the local scale. Yet, they offer little clue on the deeper dynamics of this adaptive capacity and what policy options at national, regional, and global levels may enhance it. Some aspects of enabling institutions may be expressed as "blueprints," while other aspects may require a deep contextual understanding. Enhancing the adaptive capacities of actors would seem essential to help them craft effective responses.
- *The spatial reach of responses*. The existing sub-global assessments have so far provided insufficient information on the spatial reach of responses. For instance, a response that was shown to be effective in reducing on-site ecosystem degradation may not easily be extended in scale. The social-ecological dynamics behind effective responses are site-specific and even if vertical (multilevel) collaboration exists, the spatial reach of complex responses may be limited.

Future sub-global assessments may shed more light on, and provide a better understanding of, these four issues. This would further enhance our understanding of how to design and support effective responses to ecosystem changes in the future in many parts of the world, for human well-being.

Appendix 9.1. Thirty-seven Important Responses Reported by Different Sub-global Assessments

Sub-global Assessment	Major Issues Addressed	Reported Responses and Why They Are Important
San Pedro de Atacama	declining quality and availability of resources (e.g., fiber, fuelwood, water) rising conflicts over resources and competing land uses and traditions problems with waste management	1. An Area of Indigenous Development (ADI) was designated and set up for the purpose of strengthening the social capacity of local communities to address the indicated changes and drivers. Comprehensive response in a neglected area. 2. A collective leadership structure (an Advisory Committee) was set up by the assessment team to widen and intensify stakeholders' participation across sectors in addressing the changes and their drivers. 3. Mining companies monitoring flamingos and water quality. Pressing problem acknowledged.
Caribbean Sea	deteriorating marine ecosystems (fisheries, corals, mangroves) increased sea pollution die-off of important marine organisms rising levels of poverty, especially among fishers volatile job prospects	4. Many countries collaborated to achieve a UN Resolution on integrated management of the Caribbean Sea and are pursuing a further resolution to have it declared a "special area in the context of sustainable development." This provides a framework for collaboration among Caribbean states that remains to be exploited. 5. The Barbados Coastal Zone Management project protects coral reefs and beaches. Extremely pressing issue; Barbados is totally dependent on tourism. 6. An NGO is building local capacity to manage mangroves sustainably in St. Lucia by assisting in making them Marine Reserve Areas and meeting the needs for fuelwood by reforestation projects. Important role for an NGO. 7. Co-management arrangement of the fishery with community groups in St. Lucia to halt depletion of white-spined sea urchin; first example of devolution of management rights.
India Local	forest management decline in biodiversity	8. Through the Biodiversity Act, Biodiversity Management Committees (BMCs) were created at the local level to coordinate local actions to document biodiversity changes; important devolution of power. 9. Joint Forest Management (JFM). Voluntary vertical collaboration that has become statutory, for improving the biological and physical status of forests. JFM has improved forest conditions and facilitated collaboration.
PNG	population pressure on subsistence resources commercial overfishing droughts and famines waste management biodiversity	10. During the drought of 1997–98, the government food aid program failed to take account of local communities' responses that included migration and remittances. The government mitigated starvation but also reduced the authority of local leaders or experts who know how to exploit alternative sources of subsistence. Illustrates mismatch of knowledge systems. 11. More than 30 Wildlife Management Areas (WMAs) have been established; WMAs are the only legal instrument for conservation in PNG.
Laguna Lake Basin	declining biodiversity, water quality, and productivity of rice and fish, affecting the livelihoods of more than 12 million residents living around the lake	12. Several multisectoral River Rehabilitation Councils (RRCs) were formed by the national government through the Laguna Lake Development Authority (LLDA); the RRCs are able to address social and ecological drivers. 13. In collaboration with multiple stakeholders, in 1989, the Laguna Lake Development Authority designed and implemented a lake zoning map to designate areas for fishpens, fish cages, navigational lanes, and fish sanctuary; this addressed the conflict between the fishpen operators and the open water fisheries arising from the adverse effects of fishpen fishery on open water fishery (i.e., decreased area for open water fishing, blockage of navigational routes, and blockage of water circulation).

Portugal	nutrient loss from forestry practices changes in biodiversity forest fires high transaction costs for introducing certification system for sustainable agriculture	14. Consumer pressure has led the pulp and paper industry to take voluntary initiatives to improve its forestry management in eucalyptus plantations. 15. Abandoned wheat farms were acquired by a national NGO in specific "hot spot" areas to retain wheat production and maintain the pseudo-steppe ecosystem, which would otherwise be converted into secondary forest. 16. New responses to forest fires included the introduction of a simplified land registration system to change land tenure arrangements, and the creation of a forest investment fund by taxing fossil fuels 17. ExtEnSity is an on-going development of a more economically viable and efficient certification system for sustainable (extensive) agriculture which was initiated and is being coordinated by members of the assessment team; interesting collaboration.
SAfMA Regional and Gariep	rising demand for ecosystem services equitable access to land and water political and economic changes are causing shifts in demand and supply of ecosystem services	18. The South African Water Act of 1998 revolutionized allocation rules; progressive solution focusing on human well-being. 19. Transboundary water co-management institutions, such as ORASECOM, which involves the four countries that share the Gariep basin, have been established to address water-related conflicts and benefit-sharing among countries; good international cooperation. 20. Private ownership of wildlife. Experiments to transfer use rights to wildlife began in South Africa and Zimbabwe in the early 1980s. The economic returns from trophy-hunting (in the early phase) and private safaris (dominating today) often exceed the returns from marginal cultivation or cattle ranching, giving incentives to sustainable use of wildlife. Important attempt to foster private stewardship.
SAfMA Livelihoods	declining quality and availability of ecosystem services equity over benefits from ecosystem services rural livelihoods	21. Rural households and communities employ different coping and adaptive strategies (e.g., diversification of livelihoods and land use, and increased mobility and investments in social capital like neighborhood networks, kin, and friends). Rural households sometimes respond by disengagement from the market and politics.
Sweden SU	loss of green areas and functional biodiversity reduced capacity of ecosystems to sustain ecosystem services low institutional capacity to collaborate and organize effective responses	22. A substantial part of the green areas in Stockholm was declared in 1995 as the first National Urban Park (NUP) in the world; "set asides" have been expanded—the NUP and nature reserves and other protected areas now account for 13% of Stockholm county. 23. Citizen action to protect the local environment has widened and intensified. Some proposals for exploitation and urban sprawls within Stockholm have been stopped or delayed by local groups. There is no coherent collaboration for ecosystem management.
Sweden KW	erosion of biodiversity dependent on cultivated wetlands greenhouse effect increasing risks of flooding eutrophication in the Baltic Sea innovative network organization and collaborative learning for ecosystem management	24. The Ecomuseum Kristianstad Wetlands (EKW) was established in 1989; it put into practice a conceptual and organizational innovation of collaborative learning. Application of the ecosystem approach to transform management. 25. The Crane Project was launched in 1997 to forestall conflicts between farmers and bird watchers. Hence the trust-building and legitimacy of the ecosystem approach, invested in by the EKW, was not eroded but deepened; important conflict resolution. 26. Ecosystem-based strategies to buffer flooding were acknowledged by the municipal rescue service after the flood in 2002, as a result of the increasing legitimacy of EKW.

(continues)

Appendix 9.1. continued

Sub-global Assessment	Major Issues Addressed	Reported Responses and Why They Are Important
Northern Range	declining quality and quantity of surface and groundwater declining value of amenity sites exacerbated flooding in watershed and floodplains increased incidence of landslides forest degradation health risks	27. Official plans for ecosystem protection and development have been adopted, e.g., the Northern Range Hillside Development Policy (NRHDP). 28. Civic and citizens' initiatives to protect and develop the Range have intensified; they are focused on advocacy, policy analyses, and improving awareness and empowerment of local residents. One example is Stakeholders Against Destruction (SAD) for Toco, which was responsible for stopping the construction of a port that would have changed the character of the community and had a negative impact on the environment. Illustrates increasing role of civil society. 29. Two banks have initiated environmental projects with long-term commitment. Sustainable response by the corporate sector.
Tropical Forest Margins	local livelihoods land tenure forest losses biodiversity agronomic sustainability carbon stocks hydrology	30. The Alternatives to Slash-and-Burn (ASB) program was initiated by the Consultative Group on International Agricultural Research to mobilize national competence to address these issues. 31. Land and tree tenure reform in Indonesia: the legitimacy and rights of community-managed agroforests in Lampung province were acknowledged in a government decree in 1998. This decree was the result of several years of dialogue and consensus-building involving research institutes, NGOs, local government offices, and the Krui community.
Western China	biodiversity food and water supply soil erosion desertification	32. An integrative government policy for Western China in 1999 addressed problems in five areas: reconstructing ecological resources, development of infrastructure, industry, trade, and education.
Bajo Chirripó	deforestation deteriorating quality of and inequitable access to natural resources erosion of indigenous knowledge on natural resource management	33. Indigenous peoples' leaders and some collaborating civil society groups are attempting to recover local indigenous knowledge on natural resource management. This includes putting pressure on the State to recognize ancestral domains, advocacy, and public education by indigenous peoples' leaders and their collaborating civil society organizations. Important for integrity and self-determination.
Eastern Himalayas	deforestation diversify livelihood options	34. Multisector Eco-Development Committees (EDCs) and Forest Protection Committees (FPCs) have been formed to promote wise utilization of natural resources.
Sinai	livelihoods of the Bedouins water scarcity	35. Bedouins cope by using water traps, crop selection, and diversified activities.
India Urban	loss of biodiversity, green area, and recreational and aesthetic values	36. A proposal by Pune Municipal Corporation (PMC) to convert wooded/forested hill tops and slopes to residential areas was withdrawn after a mass mobilization. PMC became aware of the issues and launched Biodiversity Management Plans instead.
São Paulo	rapid urbanization pollution loss of green space	37. The Green Belt has been acknowledged as a Biosphere Reserve by UNESCO. An integrated policy for environmental management of the São Paolo Belt is being developed but not yet assessed.

Appendix 9.2. Features of the 37 Most Important Responses Reported by the Sub-global Assessments (Knowledge Markets in Prague and Alexandria, October 2003 and March 2004, respectively). In 21 of the 37 responses, governments at the national and/or district level(s) initiated the response.

Sub-global Assessments	Short Description of Response (see Appendix 9.1 for detail)	Actors Initiating						Actors Involved						Organizational Level					Knowledge Systems			Instruments of Action					Effectiveness			
		National/district governments	International organizations	Research institutions	Business sector	Communities	Individuals/ households	National/district governments	International organizations	Research institutions	Business sector	Communities	Individuals/ households	Local	Sub-national	National	Regional	Global	Scientific	Local	Indigenous	Direct interventions	Technological innovations/ dissemination	Legal/economic devices	Organizational devices	Social, behavioral, and cognitive change	Effective	Promising	Ineffective	Bridging Organization
San Pedro de Atacama	ADI	•				•		•	•			•		•	•				•	•	•	•	•	•	•			•		
	Advisory Committee		•					•	•	•	•	•		•					•	•	•				•	•		•		•
	Mining company				•			•			•	•		•					•			•	•					•		
Caribbean Sea	UN resolution	•	•					•	•	•		•				•	•	•	•					•	•			•		
	Barbados Zone	•						•	•	•	•	•			•	•			•	•		•	•				•			
	NGO St. Lucia	•				•		•				•	•	•					•	•	•	•				•	•			•
	Co-management St. Lucia	•						•				•		•		•			•	•	•	•			•	•	•			
India Local	BMCs	•				•		•				•	•	•	•	•			•	•	•		•	•	•			•		
	JFM	•				•		•				•	•	•					•	•	•				•	•	•			
PNG	Food aid	•						•								•			•			•							•	
	WMAs	•	•			•		•	•			•	•	•		•			•	•	•			•	•				•	
Laguna Lake Basin	RRC	•						•	•	•	•	•		•	•				•	•		•		•	•	•	•			•
	Zoning map	•				•		•				•		•	•				•	•		•		•	•	•	•			
Portugal	Pulp/paper industry	•			•			•	•		•		•			•			•			•	•	•			•			
	NGO buying farms		•			•		•	•					•		•	•		•			•	•	•	•		•			
	Forest fire response	•						•			•		•	•	•	•			•					•				•		
	ExtEnSity			•	•			•	•	•	•	•	•	•		•			•	•			•	•	•	•		•		•

(continues)

Appendix 9.2. continued

Sub-global Assessments	Short Description of Response (see Appendix 9.1 for detail)	Actors Initiating						Actors Involved						Organizational Level					Knowledge Systems			Instruments of Action					Effectiveness			
		National/district governments	International organizations	Research institutions	Business sector	Communities	Individuals/ households	National/district governments	International organizations	Research institutions	Business sector	Communities	Individuals/ households	Local	Sub-national	National	Regional	Global	Scientific	Local	Indigenous	Direct interventions	Technological innovations/ dissemination	Legal/economic devices	Organizational devices	Social, behavioral, and cognitive change	Effective	Promising	Ineffective	Bridging Organization
SAfMA Regional	Water Act of 1998	•						•								•			•					•			•			
	ORASECOM	•	•					•								•	•		•					•	•		•			
	Private wildlife	•						•					•	•		•			•					•	•			•		
SAfMA Livelihoods	Coping strategies					•	•					•	•	•						•	•				•	•			•	
Sweden SU	NUP, reserves	•	•			•		•						•	•	•			•	•				•			•			
	Citizen action					•	•					•	•	•					•	•					•	•			•	
Sweden KW	Ecomuseum					•	•					•	•	•					•	•					•	•	•			
	Crane Project					•		•	•		•	•	•	•	•	•			•	•					•	•	•			•
	Flood buffer					•		•	•	•		•		•	•	•			•	•					•	•		•		•
Northern Range	NRHDP	•						•							•				•					•	•				•	
	SAD for Toco					•						•	•	•					•	•					•	•	•			
	Bank projects				•						•					•	•		•	•		•	•		•	•	•			
Tropical Forest Margins	ASB program		•					•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•			
	Tenure reform	•	•	•		•		•	•	•		•		•	•	•			•	•	•			•	•	•	•			•
Western China	Integrated policy	•						•				•		•	•	•			•			•	•	•			•			
Bajo Chirripó	Indigenous					•			•	•		•		•							•				•	•			•	
Eastern Himalayas	EDCs and FPCs					•		•				•	•	•	•				•	•	•			•	•		•			
Sinai	Coping						•						•	•						•	•					•				•	
India Urban	PMC		•			•	•		•			•	•	•					•	•					•	•	•			
São Paulo	Biosphere Reserve	•				•	•	•	•	•		•		•	•	•		•	•	•				•	•	•		•		
	TOTALS	**21**	**9**	**2**	**4**	**19**	**6**	**29**	**16**	**10**	**10**	**26**	**16**	**29**	**15**	**21**	**5**	**3**	**34**	**25**	**13**	**13**	**10**	**21**	**27**	**20**	**20**	**10**	**7**	**7**

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Chapter 10

Sub-global Scenarios

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Main Messages ***231***

10.1 Introduction **231**
10.1.1 Scenarios: Definition and Purpose
10.1.2 Scenarios in the MA Global Assessment
10.1.3 Scenarios in the MA Sub-global Assessments
10.1.4 Assessing Work in Progress
10.1.5 Analytical Framework and Organization of Chapter

10.2 Handling Uncertainties **236**
10.2.1 Key Uncertainties Identified in Sub-global Assessments
10.2.2 Describing Key Uncertainties after Identification
10.2.3 Relationships of Uncertainty to Ecosystem Services and Human Well-being

10.3 Telling Plausible Stories **239**
10.3.1 Diversity of Approaches
10.3.2 Frameworks Used to Develop Storylines
10.3.3 Systems Models, Quantification, and Spatial Explicitness

10.4 Incorporating Ecology into Scenarios **244**
10.4.1 Ecological Detail in Scenarios
10.4.2 Ecological Interactions and Surprises

10.5 Dealing with Scale **245**
10.5.1 Multi- and Cross-scale Processes in Scenarios
10.5.2 Spatial Extent, Heterogeneity, and Resolution
10.5.3 Time Horizons
10.5.4 The Linkage between Sub-global and Global Scenarios

10.6 Participating in Scenario Development **248**
10.6.1 Goals of Participation
10.6.2 Selection of Participants
10.6.3 Mechanisms of Participation
10.6.4 Roles of Participants
10.6.5 Problems Encountered in Participation

10.7 Communication in Sub-global Scenarios **250**
10.7.1 Communication Strategies
10.7.2 Scenarios in Policy Dialogues
10.7.3 Storylines for a Wider Audience

10.7.4 Spatial Representations of Scenarios
10.7.5 Community Theater and Video Techniques

10.8 Findings of the Sub-Global Scenarios 252
10.8.1 Commonalties among Scenario Findings
10.8.2 Comparing Findings across Scales
10.8.3 Summing Up: The Importance of Stakeholders

10.9 Conclusions and Recommendations for Future Assessments 255
10.9.1 Strength in Diversity
10.9.2 Lessons Learned

APPENDIX

10.1 Summary of Global Scenarios in the Millennium Ecosystem Assessment 257

REFERENCES 258

BOXES

10.1 Developing Storylines: The Caribbean Sea Approach
10.2 Nested, Multiscale Design: SAfMA and Portugal
10.3 Obstacles to Communication: Papua New Guinea

FIGURES

10.1 Key Questions Asked about the Design and Implementation of Scenario Exercises in Sub-global Assessments and Selected Answers to Four of These Questions
10.2 Two Sets of Uncertainty Axes That Could Be Used to Describe the Northern Highland Lake District, Wisconsin, Scenarios
10.3 Cascading Uncertainties in Social-ecological Systems That Might Be Captured in Scenarios
10.4 The Southern Africa Regional Assessment Scenario Development Approach
10.5 The Use of Soft-models as an Intermediate Step in the Forest and Agroecosystem Trade-offs in the Humid Tropics (Tropical Forest Margins) Scenario Exercise
10.6 Example of Spatially Explicit Scenario Outputs in the Southern Africa Regional Assessment

TABLES

10.1 Summary of the Scenario Exercises in Selected Sub-global Assessments
10.2 Major Exogenous and Endogenous Uncertainties across the Sub-global Scenarios
10.3 Steps in the Scenario Development Process
10.4 Reasons Given by the Sub-global Assessments for Excluding or Including Multiscale Considerations in their Scenario Exercises: Selected Examples
10.5 Reasons for Seeking Participation in Sub-global Assessment Scenario Development Exercises
10.6 Key Ecosystem Services Addressed in the Scenarios of Various Sub-global Assessments
10.7 Cross-mapping of SAfMA, Caribbean Sea, and Portugal Scenarios onto the MA Global Scenarios

Main Messages

Scenarios involve thinking about a wide range of futures, including both well-known trends and uncertainties. Developing scenarios is a fundamental prerequisite of strategic thinking and planning. Scenarios facilitate strategy formulation and evaluation, improve understanding of the uncertainties inherent in ecosystems, and test the robustness of particular strategies against a set of plausible futures. Unlike other decision-making techniques such as prediction, forecasting, and other single future outlooks, scenario-building is a cognitive and imaginative mechanism for decision-making. It uses more holistic, integrated, and participatory approaches to aid understanding of the intrinsic heterogeneity and uncertainty of ecosystem management. It also extends prediction and forecasting methods to provide additional and relevant alternatives to help decision-makers think, talk, plan and act imaginatively in pursuit of a more sustainable society.

Sub-global assessments used scenarios for multiple purposes, which often extended beyond the rationale for scenarios developed at the global level. Besides being used as a tool for decision-makers to plan for the future, many sub-global assessments, such as Southern Africa and the Northern Highland Lakes District of Wisconsin, also used scenarios as a means for communicating possible future changes and major uncertainties to stakeholders. In the assessments of San Pedro de Atacama, Chile, and Bajo Chirripó, Costa Rica, scenarios also have proved to be an important tool for acquiring data about stakeholder preferences, perceptions, and values. In a few cases, including Wisconsin, Caribbean Sea, and SAfMA, scenarios had a role in defining the boundaries within which discussions about management and policy options relevant to ecosystem services and human well-being could be held.

Despite being based on the MA conceptual framework, scenarios in the sub-global assessments differed greatly from the MA global scenarios. Significant differences between global and sub-global assessments in terms of key uncertainties, stakeholders involved, and scales of analysis, resulted in sets of sub-global scenarios that were different from the global scenarios. Nonetheless, a substantive link was maintained between global and sub-global scenarios in the case of the SAfMA, Caribbean Sea, and Portugal assessments.

Most sub-global assessments limited the discussions on which scenarios to develop around only one or two key uncertainties. Uncertainties were typically related to issues of technology, markets, and economic development; over half of the scenarios identified institutional arrangements/governance as a key uncertainty. Some unique examples of uncertainties included HIV/AIDS for Papua New Guinea, mining in San Pedro de Atacama, and the local legal system in India Local. Somewhat surprisingly, the Mae Chaem, Thailand, component of the Tropical Forest Margins assessment was the only assessment to explicitly address uncertainties surrounding ecosystem feedbacks.

Qualitative rather than quantitative models were most often used to explore interactions between major processes and structures, in order to provide a framework within which scenario storylines were developed. There is little documented explanation of the methods by which narrative storylines were developed in most sub-global scenarios. Many sub-global assessments noted the desire to quantify storylines, but time constraints and the lack of available models or expertise prevented all but Western China, Tropical Forest Margins (Mae Chaem, Thailand component), and SAfMA Regional assessments from undertaking such analyses.

Important scientific advances have been made in constructing nested scenarios at multiple scales. To meet the objectives of decision-makers and stakeholder groups with interests at different scales, the SAfMA assessment undertook five local-scale assessments that were nested within two basin-scale assessments, which were in turn nested within a regional-scale assessment. The Portugal assessment was also undertaken at three scales—local, basin, and national—though the local case studies were not nested within the basins that were assessed.

Scenario-building is an important method to involve stakeholders in policy formulation, and to encourage citizens to adopt policies aimed at environmental protection. The relevance, significance, and influence of the scenarios that are constructed will ultimately depend on who was involved in their development. Decision-makers will have difficulty introducing new policies designed to alter behaviors without the support of the general population. Participants in scenario building can provide essential input on the relevance of storylines being developed, and the nature of uncertainties that are important at sub-global scales.

The scale and context of a sub-global assessment are primary considerations when selecting media for communicating the findings of scenarios. Specific contextual factors include the size of the audience, their level of literacy or formal education, their religious and cultural beliefs, and the cost of reaching the audience given available resources. Specific contexts have generated some unique and creative solutions including the use of theater in SAfMA Local Livelihoods and cartoon animation in Wisconsin.

Identification of winners and losers in each scenario is an important step in guiding future responses. The inclusion of stakeholders in the scenario development and validation process helps make explicit the circumstances under which winners and losers emerge. Sub-global scenarios highlighted the importance of scale in determining winners and losers. In the Portugal assessment, one local scenario was characterized by the abandonment of agricultural fields and rural–urban migration, which is undesirable to local policy-makers. However, this scenario could be nested within the MA's Global Orchestration scenario (developed as a part of the MA's global assessment), which is characterized by economic growth and viewed by the policy-makers at higher levels as having the highest net benefits for human well-being.

Future scenario activities need to pay even greater attention to ecosystem processes. Past and current scenario work has emphasized human activities as the main drivers of change in the availability of ecosystem goods and services, without much reflection on the implications of ecological feedbacks for ecosystems and human well-being.

The large and growing number of sub-global assessment scenarios is a unique source of information within the multiscale assessment context of the MA. The sub-global scenarios, employing the common conceptual framework of the MA, allow for the critical evaluation of local variation. It seems likely that the incorporation of the findings from sub-global scenarios into the MA's global assessment would have been valuable. However, because of timing issues, the global MA scenarios did not have the opportunity to incorporate the findings of the sub-global assessments.

10.1 Introduction

The MA scenarios, unlike some earlier scenario efforts, were developed to integrate ecology into their design explicitly (Bennett et al. 2003; Peterson et al. 2003a). Ecosystems are not treated solely as passive recipients of impacts resulting from changes driven by socioeconomic systems, but are understood to play an active role in jointly determining the futures of humans and ecosystems. Changes in

the flow of ecosystem services are seen as having the potential to alter future development pathways. This is a more integrated view of how human–environment systems unfold over time than is typically assumed in scenario exercises where the goal is to assess environmental changes. (See MA *Scenarios,* Chapters 2 and 3.)

The purpose of this chapter is two-fold. First, the chapter aims to critically review how scenarios were used in the MA sub-global assessments. For those interested in conducting or designing their own sub-global assessments, it points to both the limitations and strengths of the different approaches taken. Second, the chapter aims to draw some more general conclusions, for a broader audience, on how future assessments involving scenario exercises can incorporate ecological considerations.

10.1.1 Scenarios: Definition and Purpose

A scenario is a story that offers an internally consistent and plausible explanation of how events unfold over time (Gallopín et al. 1997; Raskin et al. 2002). Sequences of events and interactions, rather than specific time scales, are usually emphasized. Decision-makers in the business community and elsewhere have employed scenarios for several decades as an approach to aid decision-making in the face of uncertainty (Chermack et al. 2001; Coates 2000; Davis 1998). Scenarios are generally useful for encouraging systematic planning in situations of uncertainty (van der Heijden 1996) or for revealing a range of dynamic processes and causal chains that lead to alternative outcomes (Rotmans et al. 2000). The intention of scenario planning is to consider a variety of possible futures that include important uncertainties, rather than to focus on the accurate prediction of a single possible future (van der Heijden 1996, Peterson et al. 2003b). Usually, scenario planners start by determining a set of focal questions or issues in conjunction with their primary stakeholders. This is followed by an assessment of the current state of a system, and identification of alternative pathways that the system might take (Peterson et al. 2003b). The focal questions often revolve around key uncertainties or unknowns in the system. The next step is to build storylines by projecting these questions into the future, which can be done either qualitatively or quantitatively. For complex systems, various methods can be used in an iterative process (Alcamo et al. 1998).

Scenarios were first used after World War II as a method for war game analysis (van der Heijden 1996). Their value was quickly recognized by Herman Kahn (Kahn and Weiner 1967) and others who developed the use of scenarios for other strategic planning applications. Scenarios were refined at Royal Dutch/Shell by Pierre Wack in the 1970s and 1980s, and Shell became a leader in the scenario approach to business planning. Today scenario development is used in a variety of different contexts ranging from political decision-making (Kahane 1992, 1998), to business planning (Wack 1985; Schwartz 1996; Davis 1998), to local community management (Wollenberg et al. 2000; Peterson et al. 2003b) and understanding global-scale environmental patterns and processes (Gallopín et al. 1997; Cosgrove and Rijsberman 2000; IPCC 2001; UNEP 2002; van Notten et al. 2003).

For ecosystem assessments, scenarios are seen as a fundamental prerequisite for strategic thinking and planning. In this context, scenarios are used to facilitate strategy formulation and evaluation, develop an understanding of the uncertainty inherent in ecological systems, and test the robustness of response strategies against a set of possible futures. Unlike other decision-making techniques that focus on a single future outlook (such as prediction or forecasting), scenario-building is a cognitive and imaginative decision-making tool. It emphasizes holistic, integrated, and participatory approaches to illuminate the heterogeneity and ambiguity inherent in ecosystem management. Scenarios extend prediction and forecasting methods, providing additional and relevant alternatives to help decision-makers think, talk, plan, and act imaginatively in pursuit of a more sustainable society.

10.1.2 Scenarios in the MA Global Assessment

Scenarios are defined in the MA conceptual framework as plausible alternative futures, each an example of what might happen under a particular set of assumptions (MA 2003). Scenarios were a key tool in the overall MA process that, along with analysis of condition and trends, and responses, provided a comprehensive assessment of ecosystems and human well-being at the global level. The MA conceptual framework envisions scenarios serving as a tool in three ways: (1) to educate local stakeholders on possible future changes in ecosystem services and human well-being; (2) to communicate the overall results of an assessment to a broader audience; and (3) to facilitate decision-making at global and sub-global scales. In the MA global assessment, four global scenarios were developed. (See Appendix 10.1). These differed primarily in terms of the assumptions made about the drivers of change in ecosystem services, and how society reacts to such change.

In the global assessments, model and scenario development consider multiscale processes and heterogeneity by disaggregating the globe into several multi-country regions (Alcamo et al. 1998; Nakicenovic et al. 2000). However, this top-down framework falls far short of embracing smaller scale phenomenon in an interactive, multiscale way.

10.1.3 Scenarios in the MA Sub-global Assessments

The sub-global assessments were strongly encouraged to undertake scenario analyses as part of their assessments. However, sub-global assessments varied greatly in how much emphasis they placed on scenarios in their overall assessment activities, and in the specific goals and focus of the scenario exercises undertaken. (See Table 10.1.) This variation in emphasis led to a wide diversity of outcomes that were not readily comparable.

Scenarios at the sub-global scale may yield results different from those that emerge from disaggregated global analyses for several reasons. First, the set of ecosystem services and the ecosystem changes of interest vary across scales. (See MA 2003, Chapter 5.). Second, the mixture of ecosystem

Table 10.1. Summary of the Scenario Exercises in Selected Sub-global Assessments (Information from specially designed questionnaires, Knowledge Markets in KM1, and KM2)

Sub–Global Assessment	Stated Goals of Scenario Analysis	Main Ecosystem Services and Human Well–being Aspects Considered	Main Methods Used to Develop Scenarios	Spatial Scale	Time Horizon
San Pedro de Atacama	communication with stakeholders	water, biodiversity, minerals, tourism, astronomical observation, agriculture	workshops and expert work	local	
Caribbean Sea	stimulate thinking about the future	fisheries, tourism	workshops and expert work	regional sub-regional	2000–50
Coastal BC		food, biodiversity, fiber and timber, runoff regulation, cultural	workshops and modeling	regional sub-national	–
India Local	assess influences of external forces on local community	food (hunting), firewood, biodiversity	based on "what . . . if" questions for management options	local	–
PNG	change ways of thinking about the future	logging, coastal mining (heavy metals), position of women, birth control	assessment and implications of the past; expert scenarios	national provincial local community	–
Portugal	for users and decision-makers	food, biodiversity, water, soil, recreation	workshops and expert work	national basin local	2050
SAfMA	tool for planning/actions particularly at local scales	water, food, biodiversity, firewood	participatory workshops including community theatre (local); modeling and expert work (basin and regional)	regional basin local	2010–50
Sweden KW and Sweden SU	prepare for surprises, information for planning; obtain stakeholder input	KW: flood buffer, wetland, security from floods SU: green area loss, biodiversity, CO_2 sequestration, recreation, health	expert work	local	2050
Northern Range	stimulate thinking about the future	fresh water, forests, cultural, runoff regulation, and biodiversity	focus groups for developing storylines	national sub-national	2000–2025
Tropical Forest Margins	analyze natural resource management options, future planning; enhance participation; inform policy-makers	biodiversity, hydrological function, forest cover	expert work (Mae Chaem); participatory scenarios (elsewhere, planning)	local benchmark sites ecoregion national	2020–30
Downstream Mekong	visualize the future, information for policy-makers, input for models	rice, shrimp, timber, firewood, medicinal plants, fresh water, security, social relation, freedom of choice		local	
Western China	information for the government, input for models	urbanization, deforestation, water	quantitative modeling	regional local	2010–20
Sinai	for local communication	water (quality/quantity)	workshops—qualitative	local	2010–20
Bajo Chirripó	get in touch with user needs	culture, forest, biodiversity, inland water	workshops—qualitative	local	<2010/2020
Eastern Himalayas	improve response options; inform policy-makers	forest, food, energy, water, biodiversity, land use, loss of life, food security	workshops—qualitative and quantitative	sub-national local	2010–15
São Paulo	envision the future; change bad situations	water, biodiversity, cultural service, soil, livelihood, social conflict	assessment and implication of the pilot expert scenario	local river basin	

(continues)

Table 10.1. continued

Sub–Global Assessment	Stated Goals of Scenario Analysis	Main Ecosystem Services and Human Well–being Aspects Considered	Main Methods Used to Develop Scenarios	Spatial Scale	Time Horizon
India Urban	share information with partners	food, water, fuel, fiber, western culture	individual consultations; literature review	local national	1950–2050
Wisconsin	Improve ecological management	Native American walleye spear fishery, tourism and sport fishing, maintenance of the "Northwoods" landscape, habitats to increase resilience of fish population, nutrient cycling (reducing impact of runoff)	initial expert assessment and scenario development; participatory scenarios workshop; scenarios redrafted by experts	local	2028
Benchmark Example					
Goulburn Broken Catchment, Australia (CSIRO)	show broad range of possible management options	water, crop production, livestock, tourism	stakeholders involved in workshops organized as expert witness jury; modeling	local	

types varies greatly within and among larger regions of the world, and it is far from certain that their resilience to human perturbations and natural disturbances is similar across these regions. Third, the types of human perturbations vary widely within and across regions with, for example, the level of industrialization of production activities. Finally, interacting drivers, institutional responses, and environmental challenges are themselves heterogeneous at the sub-global scale and typically operate on shorter time frames.

The rationale for undertaking scenarios in sub-global assessments varied considerably, often depending on the nature of stakeholder involvement. A number of sub-global assessments directly engaged local decision-makers (for example, Caribbean Sea and India Urban), and scenarios therefore played a role in local decision-making. Another set of sub-global assessments focused on local communities and thus lent themselves to educational and communication purposes (for example, San Pedro de Atacama and Sinai, Egypt); their primary purpose was to start a process of stakeholder involvement in ecosystem management processes. A third purpose of developing scenarios was to use them as input into spatially explicit models (for example, Western China and Laguna Lake Basin, Philippines).

It is important to note that while the teams conducting sub-global assessments were provided with some methodological guidelines for developing scenarios, they were encouraged to develop their own methods where necessary. Consequently, the use of different methods, combined with the focus on specific groups or issues, resulted in the development of a wide variety of scenario types.

10.1.4 Assessing Work in Progress

At the time of writing (January 2005), many sub-global assessments had yet to complete their assessment work. Moreover, scenario analysis is normally one of the final steps in an assessment, as information on drivers, uncertainties, key ecosystem services, and current trends must be available before scenario development can start. This is particularly true for the quantification of scenario results by linking storylines and models (discussed below). Therefore, this chapter often reports on plans and intentions rather than on final conclusions of the scenario exercises. Also, sub-global assessments that had completed their scenario activities usually indicated that theirs were iterative processes. Consequently, the chapter provides a snapshot in time of what is usually a much longer analytical process.

To carry out these analyses, the authors were dependent on a combination of written background documents and responses to queries provided by individual sub-global assessments, direct discussions with those involved in specific assessments, and the two Knowledge Markets (described in Chapter 2, Box 2.1). Among the authors of this chapter were representatives of 10 sub-global assessments. An example from case studies in the Goulburn Broken Catchment assessment in Australia (CSIRO Sustainable Ecosystems 2003) was used as a benchmark reference in this chapter. Though not part of the MA, this assessment is complete and was undertaken in a manner consistent with the MA conceptual framework.

10.1.5 Analytical Framework and Organization of Chapter

To help with the analysis in this chapter, an initial set of questions (Figure 10.1, left column) was developed and sent to all sub-global assessments. The list of questions was refined and additional questions were added in the course of several iterations, with inputs from the sub-global assessments. The right column in Figure 10.1 shows a partial, illustrative list of responses from the sub-global assessments to those questions, highlighting that scenarios were developed for varying purposes, that diverse approaches were used to address the technical challenges of dealing with quantification and scale, and that practical constraints of time, budget, and skills were often faced.

The rest of this chapter analyzes the sub-global assessment scenario experiences based on responses to the ques-

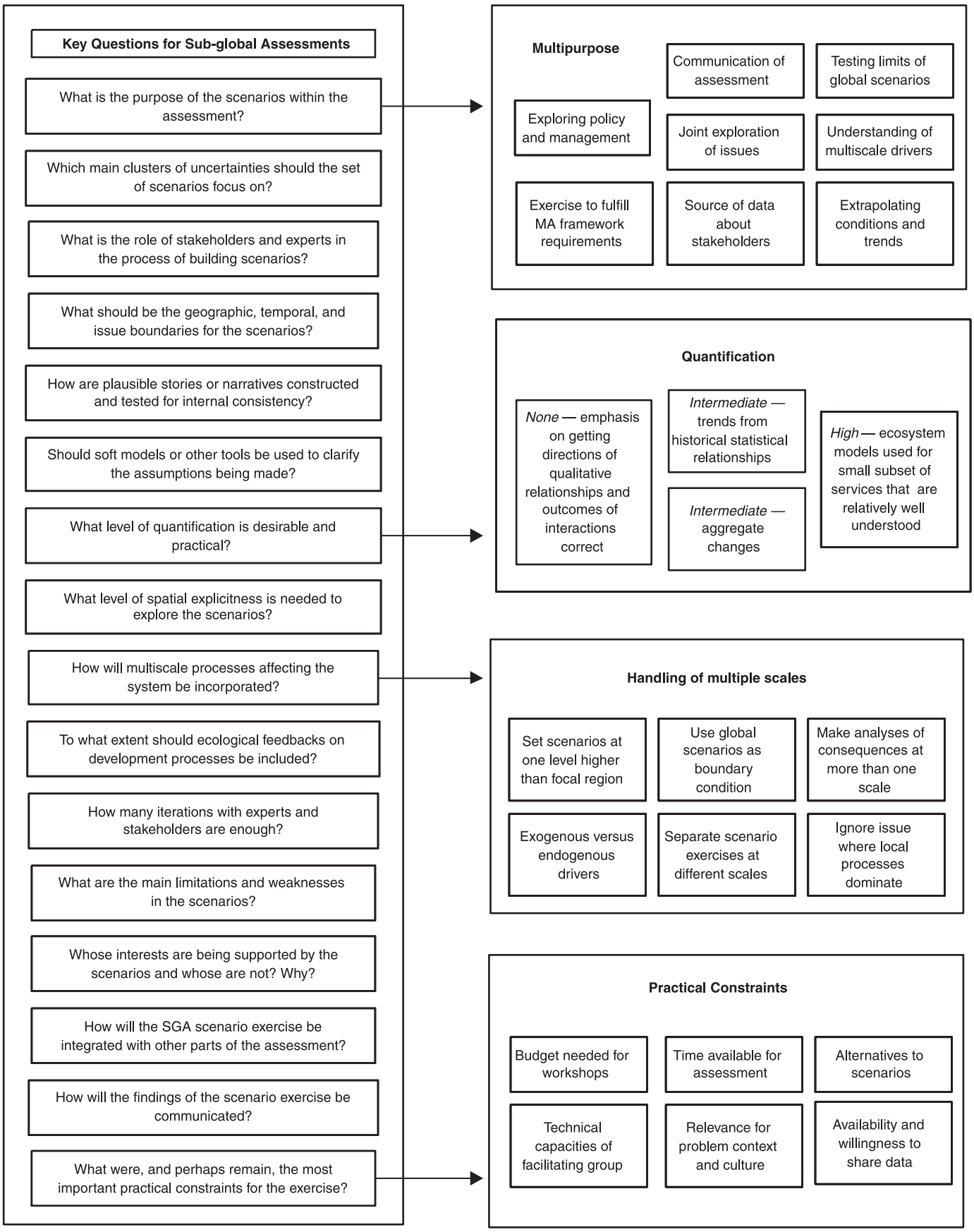

Key Questions for Sub-global Assessments
What is the purpose of the scenarios within the assessment?
Which main clusters of uncertainties should the set of scenarios focus on?
What is the role of stakeholders and experts in the process of building scenarios?
What should be the geographic, temporal, and issue boundaries for the scenarios?
How are plausible stories or narratives constructed and tested for internal consistency?
Should soft models or other tools be used to clarify the assumptions being made?
What level of quantification is desirable and practical?
What level of spatial explicitness is needed to explore the scenarios?
How will multiscale processes affecting the system be incorporated?
To what extent should ecological feedbacks on development processes be included?
How many iterations with experts and stakeholders are enough?
What are the main limitations and weaknesses in the scenarios?
Whose interests are being supported by the scenarios and whose are not? Why?
How will the SGA scenario exercise be integrated with other parts of the assessment?
How will the findings of the scenario exercise be communicated?
What were, and perhaps remain, the most important practical constraints for the exercise?
Multipurpose
Exploring policy and management
Communication of assessment
Testing limits of global scenarios
Joint exploration of issues
Understanding of multiscale drivers
Exercise to fulfill MA framework requirements
Source of data about stakeholders
Extrapolating conditions and trends
Quantification
None — emphasis on getting directions of qualitative relationships and outcomes of interactions correct
Intermediate — trends from historical statistical relationships
Intermediate — aggregate changes
High — ecosystem models used for small subset of services that are relatively well understood
Handling of multiple scales
Set scenarios at one level higher than focal region
Use global scenarios as boundary condition
Make analyses of consequences at more than one scale
Exogenous versus endogenous drivers
Separate scenario exercises at different scales
Ignore issue where local processes dominate
Practical Constraints
Budget needed for workshops
Time available for assessment
Alternatives to scenarios
Technical capacities of facilitating group
Relevance for problem context and culture
Availability and willingness to share data

Figure 10.1. Key Questions Asked about the Design and Implementation of Scenario Exercises in Sub-global Assessments and Selected Answers to Four of These Questions

tions along the following dimensions: key uncertainties; methods used to develop storylines; how ecological considerations were incorporated into the scenarios; relationship with the global scenarios exercise; participation in the scenario development process; communication of scenario process and findings; and insights from a comparison of scenario results across assessments. The chapter concludes with a summary of lessons drawn from the experiences of the sub-global assessments, which may be of particular value for future assessments.

10.2 Handling Uncertainties

Scenarios are a useful method for improving decision-making and stakeholder involvement in situations of high uncertainty. When the world is highly predictable, simpler decision-making techniques, such as prediction, forecasting, and other single-future outlooks may be useful (Peterson et al. 2003b). However, such simplicity is rare in ecosystem management. Instead, managers often find themselves confronted with complex situations and a high probability of surprise.

In describing uncertainty, clarity is essential since ''an uncertain estimate'' can mean different things to different people, ranging from an estimate just short of complete certainty to speculation (MA 2003, Chapter 7, Analytical Approaches). Uncertainty can be the result of:

- lack of information or a disagreement about what is known or knowable;
- ignorance or the possibility of surprise, both of which derive from the impossibility of prediction in social-ecological systems;
- linguistic imprecision, statistical variation, measurement error, variability, approximation, or subjective judgments.

Uncertainty can be further compounded by long time lags among driving forces, changes in ecosystem services, changes in human well-being, and responses. For ecosystem management, uncertainties may be unknowns related to the ecological system, such as how vulnerable a system is to disturbance; the social system, such as the strength of the economy over the next 50 years; or the interaction of social and ecological systems, such as how the strength of the economy will affect tourism or logging.

Fundamental uncertainties to be addressed by scenarios relate to key drivers of ecosystem change, and responses by individuals or groups. While scenarios will not resolve uncertainties, they can help stakeholders make better decisions in the face of uncertainty. For example, if the key uncertainty in a particular context is whether the economy will remain strong, decision-makers may choose a policy approach that is likely to be successful whether the economy is strong or weak. The scenario development process may also help decision-makers prioritize the most important uncertainties for further research.

10.2.1 Key Uncertainties Identified in Sub-global Assessments

The main uncertainties that the sub-global assessments attempted to capture in their sets of scenarios varied greatly. While these uncertainties may be classified in many ways, Table 10.2 groups them according to whether they are exogenous or endogenous. Exogenous uncertainties are those uncertainties related to drivers that operate primarily from outside the assessment region for which the scenario was developed. Endogenous uncertainties are related to drivers that are controlled primarily within the assessment region. For a small tourist area in Borneo, an endogenous uncertainty might relate to how much forest a community will cut, and an exogenous uncertainty might include how national and global economic activity will affect the rate of tourism to ''exotic'' locations such as Borneo. Clarifying the uncertainties in this way can improve understanding of what exogenous drivers the sub-global assessment stakeholders thought were important (but largely uncontrollable by them) and what endogenous drivers they considered important (and somewhat more controllable by stakeholders in the system).

Many sub-global assessments identified similar exogenous uncertainties, and not surprisingly, many highlighted broad clusters of issues like governance and markets. In the multiscale Southern Africa sub-global assessment, where the scenarios at different scales were developed independently, governance emerged as a key uncertainty at all scales. For some assessments, resource use outside the assessment area was also a key uncertainty.

Interestingly, the sub-global assessments shared several endogenous uncertainties as well. Common endogenous uncertainties included institutional arrangements, wealth distribution and equity, and governance. In the scenarios developed by the Caribbean Sea assessment, the main uncertainty was whether the region would continue to rely on tourism as its main source of income or whether there would be greater future diversification of the economy. The issue of economic diversification in Caribbean Sea was strongly connected to a set of governance issues such as regional cooperation and trade negotiations.

Many other uncertainties were specific to individual sub-global assessments. For example, HIV/AIDS was identified as a key uncertainty only for the Papua New Guinea sub-global assessment. This does not mean that this factor was not important in other sub-global assessments; it simply means that other scenarios did not identify it as critical for the future. Decisions about key uncertainties are based not only on what factors are unknown, but also on which factors seem, at the time of scenario development, to be the most influential but uncertain determinants of the future.

For example, for scenarios in the Northern Highlands Lake District, Wisconsin, key uncertainties included the future impact of the national economy on tourism and immigration to the region, and local institutional arrangements in the future for managing lakes and the ecosystem services those lakes provide. Changes in the national economy will affect how and where people vacation, which may affect tourism. Changes in institutional arrangements will affect the impact of tourism and other activities in the area, but the influence of these arrangements on tourism in future is uncertain given the many other factors related to the economy or the availability of internal resources that would also

Table 10.2. Major Exogenous and Endogenous Uncertainties across the Sub-global Scenarios. Exogenous uncertainties are those that are driven primarily from outside the assessment region for which the scenario was developed. Endogenous uncertainties are those that are controlled primarily within the assessment region.

Sub-global Assessment	Major Uncertainties	
	Exogenous	**Endogenous**
Tropical Forest Margins	international markets for cocoa, oil palm, timber, and other tropical forest products	human behavior
		adoption of new technologies
	global environmental concerns and actions	institutional arrangements
Western China	central government policy	rate of urbanization
		population growth
SAfMA Regional	governance (national and regional)	governance (local)
	equitability of wealth distribution	equitability of wealth distribution
Wisconsin	impact of state and national economies on tourism and immigration to the region	institutional arrangements (for managing lakes and ecosystem services)
		resilience of ecosystems to changes in local use and management
PNG	balance of power between global and Asian economies	population growth
		HIV/AIDS
San Pedro de Atacama	impact of state and national economies on tourism	institutional arrangements (for managing tourism)
		water use (by tourists, mining industry, and agriculture)
Caribbean Sea	ecosystem vulnerability to change and thresholds	governance mechanisms for ensuring equitable distribution of tourism income
	impact of international economy on tourism	
	climate (impacts on tourism, ecosystems)	
Northern Range	climate variability	distribution of wealth
	ecosystem vulnerability to change and thresholds	long-term economic prosperity
		policy responsiveness
Sweden KW	upstream water use	institutional arrangements (bridging organizations)
India Urban	national governance	rate of adoption of new technology
	empowerment of local communities	rate of urbanization
Portugal	societal attitudes toward the environment (proactive vs. reactive)	societal attitudes toward the environment (proactive vs. reactive)
	national agricultural practices and policies	national agricultural practices
	global connectedness (which also influences these practices and policies)	
Sinai	regional governance	awareness of environmental issues
		demand for ecosystem services
		local water pollution
Laguna Lake Basin	governance	population
	international politics	agricultural intensification
	international markets	industrialization
India Local	markets	institutional arrangements
	legal system (especially with regard to criminalized nomadic tribes)	

influence the amount of tourism in the area. If the Northern Highlands Lake District were to be one of the least developed areas in the American Midwest in 25 years, it may be more highly treasured and visited (and possibly then become more developed).

10.2.2 Describing Key Uncertainties after Identification

Having identified their key uncertainties, some sub-global assessment teams chose to explain their scenarios by using perpendicular axes to describe two major uncertainties, and then locating the scenarios along those axes. For example, the three Wisconsin scenarios can be arranged, post-hoc, along two axes, one from ecological crisis through to gradual ecological change, and the second from local growth to externally driven growth from retirement settlers and tourism. (See Figure 10.2.) The scenarios of the Tropical Forest Margins–Mae Chaem assessment can also be described along axes. In fact, most sets of scenarios could be described along multiple axes of uncertainty and the sub-global assessment teams could choose to explain the scenarios using axes most appropriate to the situation in which each set of scenarios were described.

It is important to note that many sub-global assessments found that the use of axes, while useful post-hoc to explain and describe the scenarios, tended to limit creativity when used as a scenario development tool. In particular, Caribbean Sea participants explained that thinking about the uncertainties in terms of clusters was more useful and allowed them to consider relationships among uncertainties. There is always a wide range of possible scenarios that can be developed, and choosing only two axes tends to narrow this range of possibilities. Therefore, at least at the early stages of scenario development, it may be more productive to embrace the widest range of possible uncertainties and avoid the use of axes.

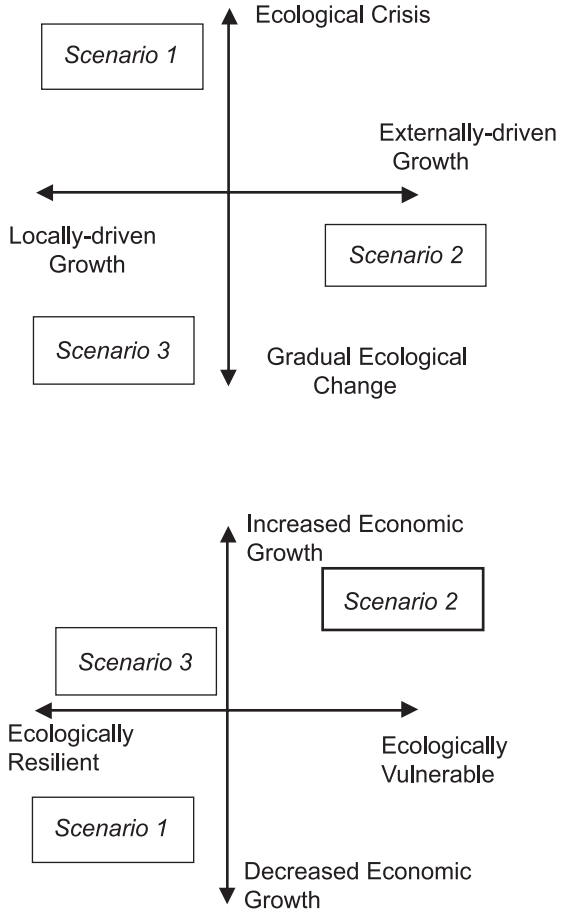


Figure 10.2. Two Sets of Uncertainty Axes That Could Be Used to Describe the Northern Highland Lake District, Wisconsin, Scenarios

10.2.3 Relationships of Uncertainty to Ecosystem Services and Human Well-being

In general, sub-global assessments selected uncertainties by focusing attention on socioeconomic drivers, with much less attention on how these uncertainties might cascade through impacts on ecosystem functions, services, and human well-being. Conceptually, the cascade could lead to either amplified or reduced uncertainties about human well-being. Figure 10.3 illustrates how this could potentially happen. In many sub-global assessments, surprises and shocks to the system and the impact on ecosystem services and human well-being are included in the scenarios. Yet the human responses to these changes are, by and large, not included, although these indirect effects could either dampen or amplify uncertainties.

If resilience is high and there are many redundancies in the system, uncertainties may affect ecosystem function without having much impact on the flow of ecosystem services. On the other hand, if there are few redundancies, small changes to ecosystem function may have a large impact on the flow of services. Management, technology, and other social factors may affect the relationship between changes in ecosystem services and human well-being. If people can use technology to substitute one service for another (for example, hunting or eco-tourism instead of timber products from a forest) or to substitute the provision of a service in the future for provision now (for example, organic farming to preserve the environment instead of conventional farming), it may be possible to adjust to a decline in ecosystem services. However, if these devices are lacking, small changes in ecosystem services may have a large impact on human well-being.

In developing the Wisconsin scenarios, it was recognized that tourists bring income to the area, but also place high demands on ecosystem services. The amount and type of tourism in the future—including whether it will involve motorized water vehicles, require the development of infrastructure, or value quiet natural areas—are examples of the kind of uncertainties that will largely determine the use of ecosystem services and affect the ecosystems' ability to provide those services. In some of the Wisconsin scenarios, increased tourism leads to higher demands on local ecosystems for nutrient cycling, sewage management, and pollution dilution. At the same time, some aspects of human well-being are improved by increased flow of money into the regional economy. Scenario development in the Northern High-

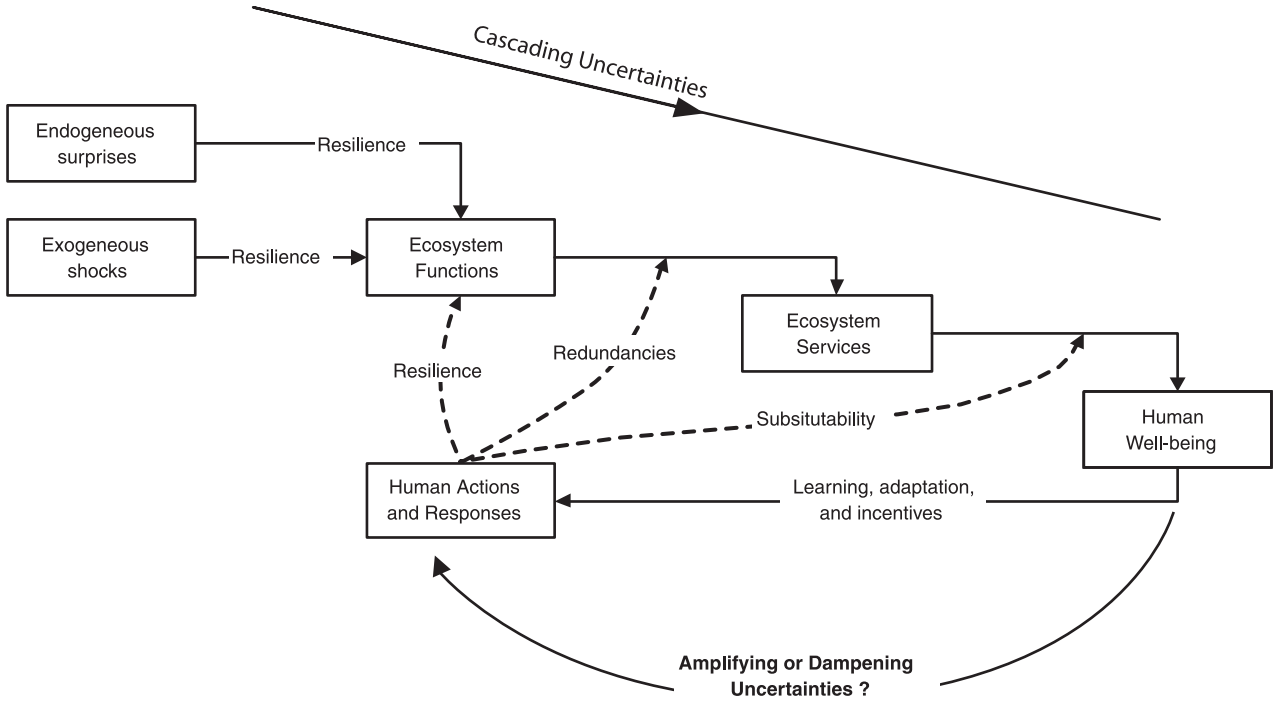


Figure 10.3. Cascading Uncertainties in Social-ecological Systems That Might Be Captured in Scenarios

lands Lake District was useful in thinking about trade-offs such as these and encouraging stakeholder discussion about important future decisions related to managing tourism and ecosystem services.

10.3 Telling Plausible Stories

10.3.1 Diversity of Approaches

A detailed methodology of how to develop scenarios was presented to all sub-global assessments and discussed with representatives of the global MA Scenarios Working Group during a scenario training workshop. (See Table 10.3, and Bennett and Zurek 2004.) Although the ''scenario cookbook'' provided a detailed guide, sub-global assessments were encouraged to adapt the methods to their local circumstances. Unfortunately, not all sub-global assessments were completely clear on what type of scenarios should be developed and this, combined with specific local interests and limited financial resources, led to a wide variety of scenario products that, more often than not, were less elaborate than initially envisioned.

Step-by-step approaches to developing scenarios were documented by the SAfMA assessments and by Caribbean Sea. SAfMA Regional identified governance as the major uncertainty, leading to bifurcation in the storylines for the region over the next three decades. The two resulting scenarios were fleshed out by filling in the MA conceptual framework diagram as a causal diagram. These key bifurcations were translated from the regional scale to the Gariep Basin scale to local studies in a ''cascade'' of progressively refined and locally relevant scenarios (Biggs et al. 2004). The first scenario, named ''African Patchwork,'' relied on projecting current trends (that is, a business-as-usual scenario). The second scenario, ''African Partnership,'' presented a vision of the future based on the strong political support for the New Partnership for Africa's Development. (See Figure 10.4).

Many countries have similar politically endorsed foresighting initiatives, which usually use either *forecasting* (Wollenberg et al. 2000; Rotmans et al. 2000) or *backcasting* (Dreborg 1996; Robinson 1982; Robinson 2003) scenario development approaches to develop a desirable vision of the future based on expected or desired policy directions. One example of a forecasting scenario is the Stockholm Urban assessment, in which a newly developed governmental program for protected areas was evaluated in terms of how it will affect key organizations (for example, NGOs or political bodies) and local stakeholders active in the management of urban green areas. In the case of the Caribbean Sea assessment, both regional and global experts were involved in scenario development. (See Box 10.1 for a summary of the Caribbean Sea scenario development approach.)

10.3.2 Frameworks Used to Develop Storylines

In developing scenarios at the sub-global level, assessments made use of different frameworks to structure their work. Some assessments, such as the Eastern Himalayas, started off by trying to map their local situation directly to one of the MA global scenario archetypes. Other assessments used diagrams with perpendicular crossed axes representing major direct and indirect drivers. The four resulting quadrants then represented the major storyline permutations (examples include Portugal, Sweden SU, and Caribbean Sea). Anticipated changes in drivers were then assessed qualitatively, and storylines developed.

Table 10.3. Steps in the Scenario Development Process

When	Step	Who
Before first workshop	Decide on purpose of scenario and stakeholder involvement	Core team in consultation with main stakeholder groups
At first workshop	Icebreaker: Getting people to think about the long-term future	Stakeholder group with core team facilitation
	Introduce the concept of scenarios	Core team
	Back casting exercise[a]	Stakeholder group with core team facilitation
	Identify main areas of uncertainty[a]	Stakeholder group with core team facilitation
	Develop focal questions to be addressed by scenarios[a]	Stakeholder group with core team facilitation
	Identify main drivers of change[a]	Stakeholder group with core team facilitation
	Develop first set of storylines	Stakeholder group with core team facilitation
	Decide on modeling capacity	Stakeholder group and core team
Between workshops	Prepare documentation material of first workshop	Core team
	Model runs	Modeling teams
At the second workshop	Critically assess storylines and incorporate model results[a]	Stakeholder group with core team facilitation
	Identify important surprises[a]	Stakeholder group with core team facilitation
	Identify implications of scenarios for the main stakeholder groups in the area	Stakeholder group with core team facilitation
	Decide on final storylines	Stakeholder group with core team facilitation
	Evaluate the implications of each scenario for addressing identified uncertainties	
Optional	Wider stakeholder feedback session and scenario iterations	Core team facilitation
After workshop	Final write up of scenario storylines and their implications	Core team
	Dissemination of scenarios write-up	Core team

[a] The sequencing of these steps can vary.

10.3.2.1 Portugal

In the first phase of the national scale Portugal assessment, one of the two major axes of change was related to society's attitudes toward environmental change—reactive versus proactive. The second axis related to agricultural practices in Portugal, particularly the effects of agricultural policies on those practices. In these independently created scenarios, the societal attitudes axis was shared with the global MA scenarios. This convergence between global and sub-global scenarios meant that some of the quantitative modeling already done in the global scenarios could be ground-truthed in Portugal. It also provided the opportunity to scale down the global scenarios, where in the second phase of the assessment, the global scenarios were used to provide boundary conditions for the national scenarios in Portugal. The local assessment of Sistelo in Portugal developed scenarios independently, the results of which were later integrated into the national scenarios (Pereira et al. in review).

10.3.2.2 Tropical Forest Margins–Mae Chaem, Thailand

The Tropical Forest Margins–Mae Chaem scenarios also started with two contrasting perpendicular axes. The first captured the character of linkages to outside regions (localized versus globalized), and the second captured the sectoral composition of economic development (agricultural versus diversified). Taken together these two axes were seen as determining a third composite axis of ''connectivity'' (or cluster of processes), which appeared to capture an essential cluster of features in each of the quadrants that were subsequently developed into each of the contrasting scenarios.

10.3.2.3 Southern Africa Assessments

The SAfMA nested assessments adopted an experimental approach to multiscale scenario development. Each SAfMA component assessment selected methods designed to answer the questions relevant at its particular scale, while also attempting to retain multiscale comparability. The local scale data were largely collected using participatory methods, while the basin and regional scale studies primarily made use of published studies, national and international databases, and modeling approaches.

At the basin scale, existing scenarios previously produced for the region were first explored. Subsequently, the feasibility of adapting elements of the MA global scenarios was investigated. After reviewing existing scenarios, the choice was made to develop a set of scenarios with input from stakeholders and the other Southern Africa component as-

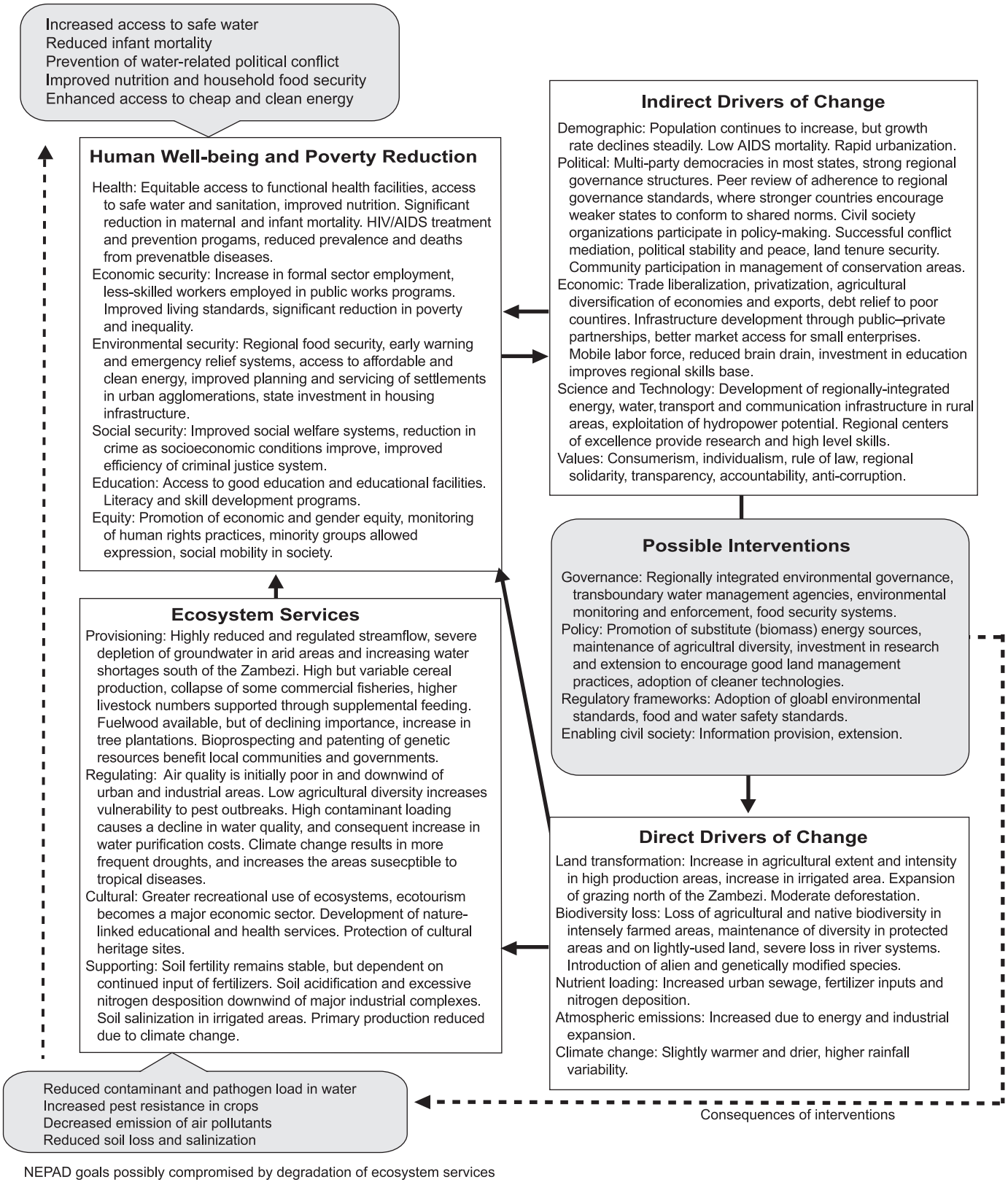

Increased access to safe water
Reduced infant mortality
Prevention of water-related political conflict
Improved nutrition and household food security
Enhanced access to cheap and clean energy
Human Well-being and Poverty Reduction
Health: Equitable access to functional health facilities, access to safe water and sanitation, improved nutrition. Significant reduction in maternal and infant mortality. HIV/AIDS treatment and prevention progams, reduced prevalence and deaths from prevenatble diseases.
Economic security: Increase in formal sector employment, less-skilled workers employed in public works programs. Improved living standards, significant reduction in poverty and inequality.
Environmental security: Regional food security, early warning and emergency relief systems, access to affordable and clean energy, improved planning and servicing of settlements in urban agglomerations, state investment in housing infrastructure.
Social security: Improved social welfare systems, reduction in crime as socioeconomic conditions improve, improved efficiency of criminal justice system.
Education: Access to good education and educational facilities. Literacy and skill development programs.
Equity: Promotion of economic and gender equity, monitoring of human rights practices, minority groups allowed expression, social mobility in society.
Indirect Drivers of Change
Demographic: Population continues to increase, but growth rate declines steadily. Low AIDS mortality. Rapid urbanization.
Political: Multi-party democracies in most states, strong regional governance structures. Peer review of adherence to regional governance standards, where stronger countries encourage weaker states to conform to shared norms. Civil society organizations participate in policy-making. Successful conflict mediation, political stability and peace, land tenure security. Community participation in management of conservation areas.
Economic: Trade liberalization, privatization, agricultural diversification of economies and exports, debt relief to poor countires. Infrastructure development through public–private partnerships, better market access for small enterprises. Mobile labor force, reduced brain drain, investment in education improves regional skills base.
Science and Technology: Development of regionally-integrated energy, water, transport and communication infrastructure in rural areas, exploitation of hydropower potential. Regional centers of excellence provide research and high level skills.
Values: Consumerism, individualism, rule of law, regional solidarity, transparency, accountability, anti-corruption.
Possible Interventions
Governance: Regionally integrated environmental governance, transboundary water management agencies, environmental monitoring and enforcement, food security systems.
Policy: Promotion of substitute (biomass) energy sources, maintenance of agricultral diversity, investment in research and extension to encourage good land management practices, adoption of cleaner technologies.
Regulatory frameworks: Adoption of gloabl environmental standards, food and water safety standards.
Enabling civil society: Information provision, extension.
Ecosystem Services
Provisioning: Highly reduced and regulated streamflow, severe depletion of groundwater in arid areas and increasing water shortages south of the Zambezi. High but variable cereal production, collapse of some commercial fisheries, higher livestock numbers supported through supplemental feeding. Fuelwood available, but of declining importance, increase in tree plantations. Bioprospecting and patenting of genetic resources benefit local communities and governments.
Regulating: Air quality is initially poor in and downwind of urban and industrial areas. Low agricultural diversity increases vulnerability to pest outbreaks. High contaminant loading causes a decline in water quality, and consequent increase in water purification costs. Climate change results in more frequent droughts, and increases the areas susecptible to tropical diseases.
Cultural: Greater recreational use of ecosystems, ecotourism becomes a major economic sector. Development of nature-linked educational and health services. Protection of cultural heritage sites.
Supporting: Soil fertility remains stable, but dependent on continued input of fertilizers. Soil acidification and excessive nitrogen desposition downwind of major industrial complexes. Soil salinization in irrigated areas. Primary production reduced due to climate change.
Direct Drivers of Change
Land transformation: Increase in agricultural extent and intensity in high production areas, increase in irrigated area. Expansion of grazing north of the Zambezi. Moderate deforestation.
Biodiversity loss: Loss of agricultural and native biodiversity in intensely farmed areas, maintenance of diversity in protected areas and on lightly-used land, severe loss in river systems. Introduction of alien and genetically modified species.
Nutrient loading: Increased urban sewage, fertilizer inputs and nitrogen deposition.
Atmospheric emissions: Increased due to energy and industrial expansion.
Climate change: Slightly warmer and drier, higher rainfall variability.
Reduced contaminant and pathogen load in water
Increased pest resistance in crops
Decreased emission of air pollutants
Reduced soil loss and salinization
Consequences of interventions
NEPAD goals possibly compromised by degradation of ecosystem services

Figure 10.4. The Southern Africa Regional Assessment Scenario Development Approach. The Southern Africa Regional assessment made use of the MA conceptual framework to synthesize several existing regional scenarios. The African Partnership scenario was based on an action plan called the New Partnership for Africa's Development, a politically endorsed initiative for the economic and social development of the continent. By mapping the main aspects of the action plan into the framework, it was possible to identify targets that may be comprised by the degradation of ecosystem services.

BOX 10.1

Developing Storylines: The Caribbean Sea Approach

The Caribbean Sea assessment pursued a two-part approach to developing scenarios, first encouraging stakeholder involvement, and then refining and testing scenarios.

Part I: Stakeholder involvement (conducted separately in small breakout groups)

1. *Assess current knowledge and the current state of the system*
   - List key historical eras, key actors, external forces affecting the region, and ecosystem services.
2. *Identify a focal issue or issues*
   - List hopes and fears for the future to determine focal questions that might drive scenario development.
3. *Identify alternative trajectories and branch points*
   - Identify key sources and threats to the resilience of the region (the ability to adapt to future surprises). Focal questions for Caribbean marine ecosystems were developed based on: What is the biggest concern for the region in the future? What are the factors that can make this region better able to cope with whatever the future brings?
4. *Build scenarios*
   - Ask breakout groups to come up with a set of storylines, based on the focal questions and considering the major historical eras and vulnerabilities of the region. Groups were asked to do this in 1 hour to create a sense of urgency. Each group was then asked to present their set of scenarios in a plenary session.

Part II: Refine and test the scenarios (conducted with a single, small focus group)

5. *Assess the scenarios*
   - Are there certain themes emerging? Can we come up with a set of four or so that seem to make sense together? What are the critical contrasts among the scenarios? What are the recurring themes? Are the trends/events plausible? What trends/events are useful for illustrating key themes or concepts?

   Does the set of scenarios address the focal questions?
6. *Shocks and surprises*
   - Come up with a list of shocks and surprises that might happen and ask how the world would respond under each of the scenarios.
7. *Use this analysis to refine a final set of scenarios.*

sessments at the regional and local scale. At the local scale, future scenarios for three local sites within the Gariep Basin were constructed during a workshop for project team members using the following steps:

- Static drivers of change were identified. These are known drivers and trends that will not change within the time horizon considered but will have an influence on the future that unfolds.
- Assumptions were identified and listed, especially those relating to dynamic variables that have the potential to change during the time horizon considered, but were not expected to change.
- The key uncertainties were identified. These are dynamic variables that were expected to change during the forecast period and to influence the outcome of the scenarios. Changes in the influence of these drivers, or possible options around key uncertainties, were then elaborated for each driver.
- Drivers of change were ranked from potentially the most influential to the least.
- Correlations between drivers were identified, and where detected, the least influential driver was omitted.
- A suite of proto-scenarios was then developed from combinations of different pathways for each of the most influential drivers.
- Each resultant scenario was then assessed in terms of its feasibility and probability. Those scenarios deemed unfeasible or improbable were then omitted.

From within the final suite of scenarios, a subset was selected, so that each scenario represented a cluster at different stages along the primary iteration. These were then fleshed out in narrative form with respect to the state of issues/descriptors of interest under such combinations of drivers of change.

In summary, most sub-global assessments used some variant of the MA methodology to develop largely qualitative stories based on major drivers of change. There was little evidence of the use of causal diagrams, but the San Pedro de Atacama and SAfMA Regional assessments demonstrated a relatively simple approach to filling in the MA conceptual framework to accomplish the same end.

10.3.3 Systems Models, Quantification, and Spatial Explicitness

The most common approach among sub-global assessments was to opt for *qualitative scenarios* that relied either on unstructured narratives (for example, India Urban and Eastern Himalayas) or more structured sequences of events (for example, Coastal BC, Sinai, and San Pedro de Atacama). This is a logical first step in scenario development and the most effective way to engage a wide variety of stakeholders. Many sub-global assessments noted the desire to quantify storylines, yet in many cases, time constraints and the lack of a calibrated and validated quantitative model for the assessment area limited the possibilities for linking to models. Quantitative scenarios based on computable model-based exercises (such as Western China and SAfMA Regional) were therefore less common. However, the rarity of quantitative analysis could well be a consequence of the relatively short period of sub-global assessment work considered in this chapter. In the future, many sub-global assessments might engage in quantitative analyses of the various scenarios.

Structural or soft models and event sequence diagrams were used in the Tropical Forest Margins–Mae Chaem scenarios to help clarify the logical assumptions behind each of the stories. (See Figure 10.5.) These were prepared before the text was written, and then partly revised and adjusted as the storylines became richer and more specific. Within the India Urban assessment, a qualitative, structural diagram with feedbacks based in implicit data and relationships was used. Several case studies in the Goulburn Broken Catchment assessment in Australia (CSIRO Sustainable Ecosys-

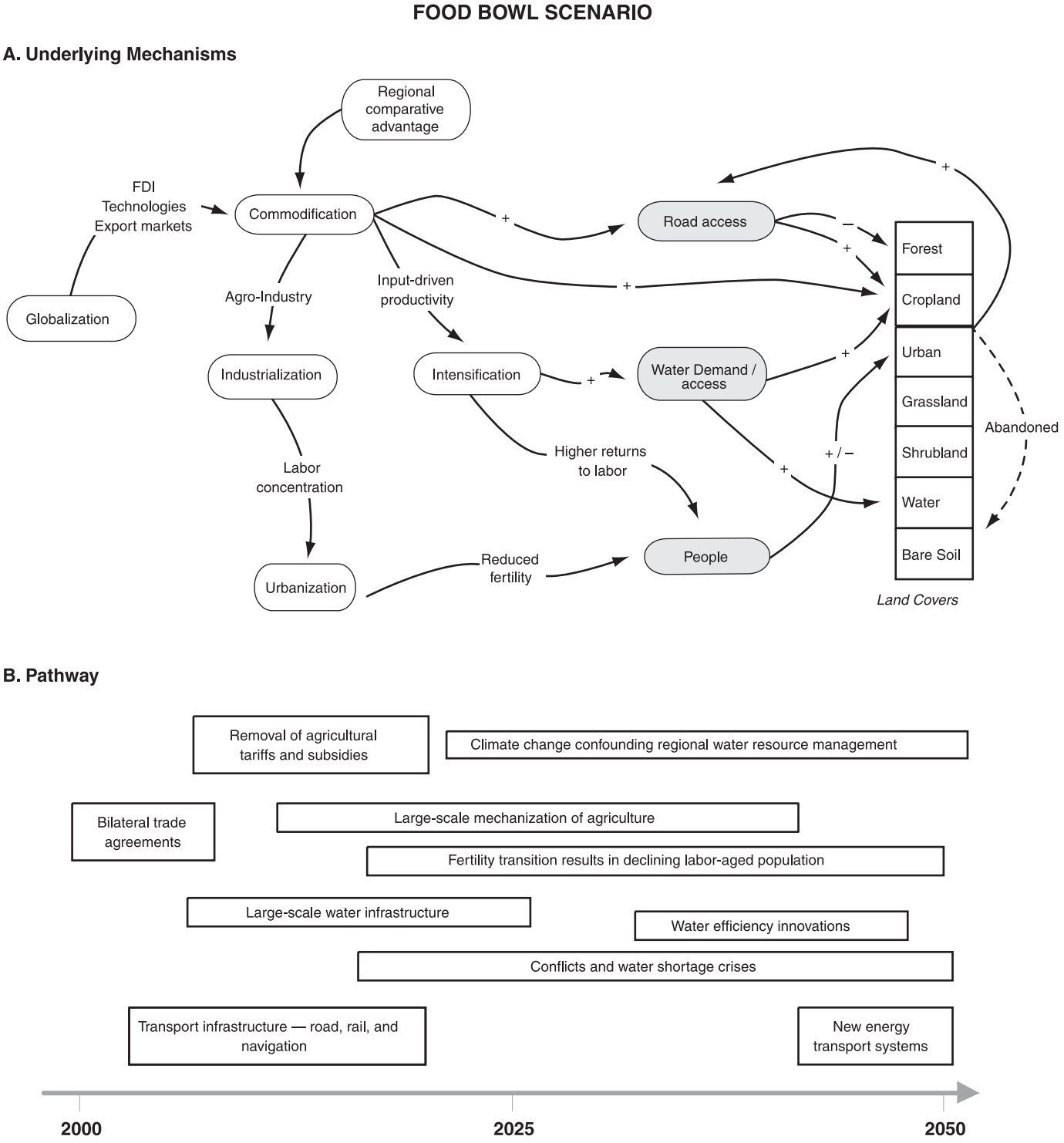


Figure 10.5. The Use of Soft-models as an Intermediate Step in the Forest and Agroecosystem Trade-offs in the Humid Tropics (Tropical Forest Margins) Scenario Exercise

tems 2003) made use of explicit system dynamics models quantifying ecological processes and, in some cases, financial returns.

Some scenario exercises produced high-resolution maps of land use and land cover. In Western China, scenarios were developed specifically to link to a Geographic Information System-based model, and scenarios were therefore quantitative rather than qualitative. Several other sub-global assessment groups indicated that they plan to use spatially explicit models at a later stage (Laguna Lake Basin, Downstream Mekong) using rather simple but easily applicable models like CLUE-S (Verburg et al. 2002). In SAfMA Regional, extensive use was made of various models (Biggs et al. 2004) to assess the effects of different scenarios on biodiversity. Figure 10.6 shows the results of runs of the IMAGE model (Alcamo et al. 1998) for two regional sce-

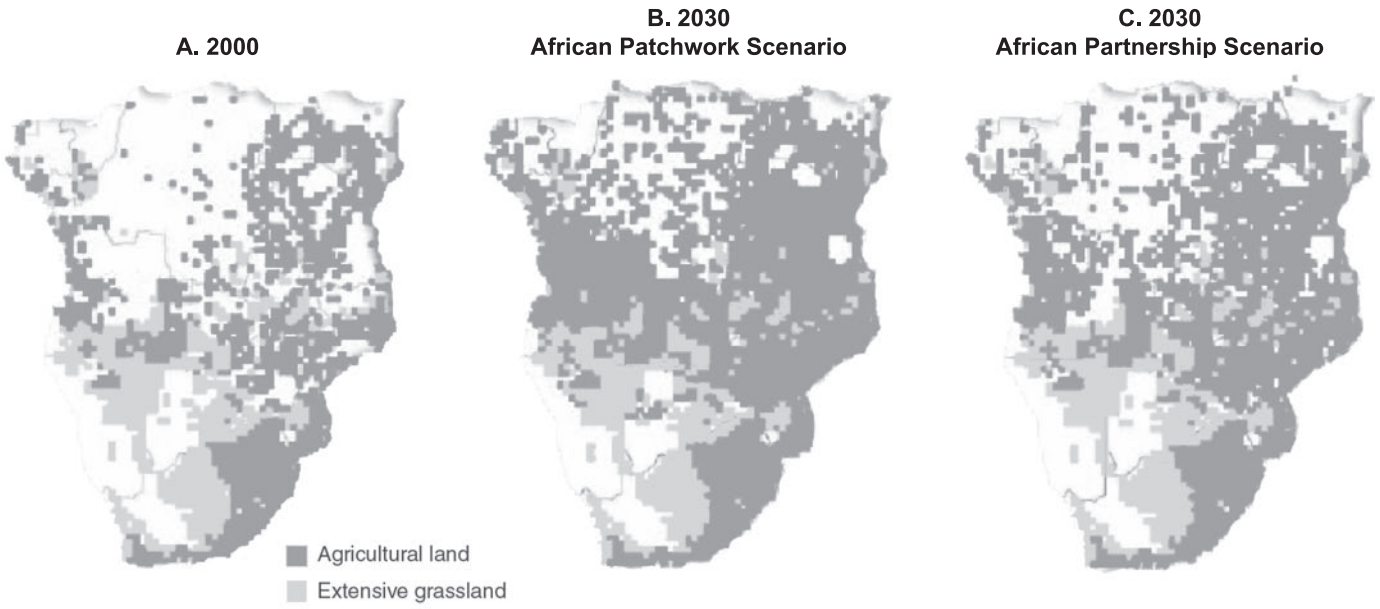


Figure 10.6. Example of Spatially Explicit Scenario Outputs in the Southern Africa Regional Assessment. Projections of land cover change using the IMAGE model for the (b) African Patchwork and (c) the African Partnership scenarios. (Scholes and Biggs 2004)

narios, African Patchwork and African Partnership. In this application, a downscaled version of an existing global model was used, showing one way in which scenario quantification can be done.

As a rule, scenario development exercises that used quantification did so for only a restricted part of the overall issues they set out to explore and assess. This is a sensible approach since frequently the objective of scenario development is to allow exploration of uncertainties, surprises, and thresholds, not all of which are easy to model quantitatively.

10.4 Incorporating Ecology into Scenarios

The use of scenarios in the MA was intended to differ from earlier exercises in that the MA explicitly set out to integrate ecology into the scenarios design (Bennett et al. 2003). Ecosystems were not to be treated solely as passive recipients of the impacts of changes in socioeconomic systems, but also as having a role in jointly determining social futures. Changes in the flow of ecosystem services are seen as potentially altering future development pathways. This view of how integrated social-ecological systems unfold over time is much more co-evolutionary than in scenario exercises where the goal is only to assess environmental changes.

10.4.1 Ecological Detail in Scenarios

Despite the MA's focus on ecology, the ecological detail in most sub-global assessment scenarios was relatively weak. While the impact of external and internal shocks to ecosystems and the consequences for ecosystem services and human well-being were considered by the sub-global assessments, the scenarios developed did not explicitly include ecological feedbacks (see also Figure 10.3). Usually, the focus was on socioeconomic factors and the consequences of these for variables such as land use change, biodiversity, or food production. The examples below draw on two completed assessments that did attempt to include ecological feedbacks.

Several case studies in the Goulburn Broken Catchment assessment (CSIRO Sustainable Ecosystems 2003) made use of explicit system dynamics models to explore alternative land management scenarios. For example, in the Goulburn River Floodplain, Australia, case study, dynamic models of biophysical processes and a land management model were developed to explore alternative land management strategies. In this landscape, the alternative land uses were combinations of cropping, grazing, and conservation. The scenarios identified strategies to maximize financial returns and conservation value, meet targets for protection of different vegetation types, and create mixed land uses to achieve multiple goals. Through a model interface, this approach helped users to explore trade-offs and spatial interactions among ecosystem services.

The Northern Highlands Lake District of Wisconsin has been a field laboratory for ecological research for several decades, and a site for long-term ecological research funded by the U.S. National Science Foundation since 1982. The assessment analysis benefited from a tremendous baseline of ecological (as well as demographic and economic) information. Thus the scenario exercise, focusing on lake ecosystems, was able to bring substantial ecological explicitness into the analysis. For example, narratives on how different actors would use various ecosystem services, what may drive changes in these services (for example, biological invasions, climate, human migration), and the linkages between these, were constructed.

The India Urban assessment included the negative feedback of the constant drain of soil nutrients, water, and carbon to the sea and atmosphere due to urbanization and

declining annual productivity, as well as overall scarcity of food, water, and fuel services. In SAfMA, modeling exercises were used that included feedbacks, while in the Caribbean Sea assessment, the negative feedback on the economy of the entire region that emerges from ecosystem (coral reef) destruction by overfishing and tourism was explored.

10.4.2 Ecological Interactions and Surprises

Several sub-global assessments considered the possibility of ecological surprises. For example, the India Urban assessment addressed potential surprises such as global increases in flooding and the collapse of transport systems due to unanticipated abrupt climatic change; scenarios discussed how cities affected by such calamities might sink, starve, and perish, while some upland subsistence farmer communities could survive.

The Wisconsin assessment has the best example of using scenarios to consider the implications of ecological surprises (Carpenter et al. 2003; Peterson et al. 2003a). In the ''Walleye Commons'' scenario, conflict over resource use interacts with a series of unexpected environmental changes, including climate shifts that affect winter tourism, fishery collapses, and zoonotic diseases. These unexpected events provoke conflicts as different groups blame each other for the resulting losses. The net effect of the social and ecological breakdowns is an exodus of many people from the region.

10.5 Dealing with Scale

The MA design process placed strong emphasis on gaining better understandings of interactions between human activities and ecosystem services at multiple scales. In the light of Chapter 4 of this volume, which examines the scale-related issues in conducting an assessment, and of Chapter 5 of the MA conceptual framework (MA 2003), the discussion in this chapter addresses the specific challenges in developing multiscale scenarios.

10.5.1 Multi- and Cross-scale Processes in Scenarios

Multiscale processes were taken into account in *all* sub-global assessment scenarios, but often this was limited to incorporating ''exogenous'' drivers in the construction of scenarios and making general comparisons with global scenario exercises. Such a limited approach makes sense where cross-scale interactions are primarily top-down or relatively unimportant in comparison with the processes that take place at the scale of primary interest of an assessment. Above all, this keeps the analysis simpler—one of the main reasons given by several sub-global assessments for declining to invest more resources for including multiscale considerations in their scenarios. (See Table 10.4.)

Table 10.4. Reasons Given by the Sub-global Assessments for Excluding or Including Multiscale Considerations in their Scenario Exercises: Selected Examples

Reasons for Excluding Multiscale Considerations	Reasons for Including Multiscale Considerations
The importance of the local issue exceeds any possible global development *Example: Sweden KW.* Recent flooding events have put the question of protection against flood water high on the agenda. The main issue is whether dikes should be raised or new wetlands should be created. Global issues like climate change are important, but the issue is clear and mostly local.	**Regional scenarios that bridge the local and the global already exist** *Example: SAfMA.* Scenarios in this assessment built on a number of sub-Saharan scenarios that already existed.
National government is dominant in the organization of national resources to implement sustainability goals *Example: Western China.* China's economy is no longer centrally planned, and local government and people have significant roles in taking decisions on local affairs. At the same time, China is affected by global change and the international market economy, for example through the accession of China to the WTO. Nevertheless, because China is very large and has many nationalities, the national government is dominant in the organization of national resources and the Western China sub-global assessment was structured accordingly.	**Links between regional and global levels are strong and evident** *Examples: Caribbean Sea.* This area of the Caribbean Sea includes parts of around 30 countries at the regional level, which facilitates the link to global scenarios. Additionally, many issues are the same at both regional and global levels. *Portugal.* Scenarios were first developed independently at the national level, and proved so similar to the global scenarios that the global scenarios were taken and adapted to Portugal instead.
Information at the regional level is inaccessible and an analysis is impossible for security reasons *Example: Sinai.* The Sinai desert is a strategically important region; information at any level above the local is scarce and often not accessible.	**The link between the local and the global is strong.** *Example: Sweden SU.* In general, less isolated local areas have more connections with the regional and global levels and, consequently, translation of issues across scales is easier.
It is difficult to link the local level to global scenarios *Example: Bajo Chirripó.* This assessment focused on the needs and concerns of the indigenous people in the area. The user needs here are so different that linking to global level scenarios was difficult.	

Some sub-global assessments used the global scenarios to set boundary conditions for the scenarios developed in their assessments. The SAfMA local assessments used basin-level scenarios to set their boundary conditions; and the basin-level scenarios in turn considered regional scenarios for the same purpose. In the Caribbean Sea assessment, scenarios were primarily targeted at the regional level, and the global scenarios were explicitly used as boundary conditions.

To incorporate more complexity into their scenarios, however, a few assessments—notably SAfMA and Portugal—used more sophisticated multiscale scenario methodologies. Although these two assessments were exceptions

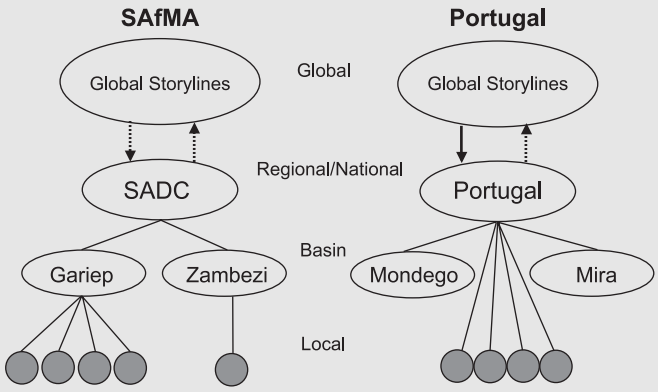
rather than the rule, they demonstrate the potential of employing multiscale methodologies by developing internally consistent stories at more than one scale. In the Southern Africa set of assessments, there were three levels of assessment, each involving at least some scenario activities. Though linked, these separate scenario exercises primarily addressed the particular needs and goals of each of the component assessments. The Portugal assessment also worked at multiple scales, but cases at the local scale were not completely nested in the larger-scale scenarios. (See Box 10.2.)

The Tropical Forest Margins–Mae Chaem scenarios were planned as one of six sets of scenarios to be developed for the benchmark sites of the Alternatives to Slash-and-Burn consortium in six countries worldwide (Brazil, Peru, Cameroon, Indonesia, Thailand and the Philippines). At the same time, these scenarios were also linked with two additional new exercises in northern Thailand and the Mekong River Basin (across the five countries of southwest China, Laos, Thailand, Cambodia, and Viet Nam). The geographical scope of the scenarios in each case was set at a scale broader than the focus area for assessment and simulation of landscape trajectories. This was considered extremely important in these assessments because of the major assumptions on historical, cultural, trade, investment, and information links, and the structure of the regional economy. At the time of writing of this report, scenarios for a rural area (the Mae Chaem watershed) have been completed, and those for an urbanizing area (greater Chiang Mai) were underway.

Explicit nesting of scenarios is advantageous, but it also introduces increased complexity in scenario work. Nesting allows for some preliminary consideration of the plausibility of particular scenarios unfolding at one scale in the face of changes at another. When these mixtures are cross-tabulated, many ''discordant'' combinations can be eliminated as unstable and unlikely to persist. For example, it is hard for northern Thailand to pursue a strong, locally oriented development trajectory while the wider region unfolds in a

BOX 10.2

Nested, Multiscale Design: SAfMA and Portugal



Within the Southern Africa assessment, five local scale assessments, each covering the area of a community or local authority, were nested within two basin-scale assessments, which in turn lay within an assessment of the greater SADC region. All contributed to the MA global assessment, but were not linked to the global scenario storylines (dotted lines in the figure).

Scenario development followed the same general design. SAfMA derived two scenarios by synthesizing information from several recent scenario exercises in the region, rather than developing its own scenarios. The classification of existing regional and global scenarios into a limited number of archetypes provided the basis for interaction and comparison with the MA global scenarios working group. The Gariep Basin assessment used four scenario archetypes and explored what it would mean for ecosystem services and human well-being if the conditions of each of the archetypes prevailed in the basin.

The local community assessments within the Gariep Basin focused on identifying the key drivers in the different study areas. The likely permutations of these drivers were considered and led to the development of three scenarios. The local Gorongosa-Marromeu assessment (within the Zambezi Basin) used scenarios in the sense of ''wind-tunnels'' for testing the robustness of policy and management responses in alternate plausible worlds.

The Portugal assessment was undertaken at three scales: national, basin, and local. There were two basin assessments and four local assessments. The local case studies were not within the basins studied, and covered different reporting units (systems) of the national assessment. These reporting units included a very small rural community (mountain system), two farms (cultivated systems), and a biological research station (Montado system). National scenarios were first developed independently and in a second phase compared with the global ones.

One of the two axes of the Portugal scenarios was similar to one of the global ones, and congruence between the Portugal and global scenarios could be established. Thus the Portugal assessment decided to adopt the global scenarios as boundary conditions for the national scenarios, and developed storylines accordingly. This also allowed the use of the quantitative modeling work already done in the global scenarios, and provided a test for the scaling down and regional calibration of the global scenarios.

The Portugal assessment plans to develop scenarios for basin and local assessments also using the global scenarios. Nevertheless, the local community assessment of Sistelo developed independent scenarios that were subsequently integrated with the national scenarios.

highly globalized and interconnected manner. Although this approach of examining ''discordance'' among scenarios created at different levels is pragmatic, it still falls short of allowing for dynamic feedback between scenarios at various scales.

10.5.2 Spatial Extent, Heterogeneity, and Resolution

The sub-global assessment scenario exercises varied substantially with regard to spatial extent, boundary setting, and handling of spatial heterogeneity.

The spatial extent at each level was typically defined either by socioeconomic (for example, village, city, nation) or biophysical (for example, watershed) boundaries. For example, even within the various SAfMA component assessments, different criteria were used to set boundaries. SAfMA Regional was defined by a political grouping of countries (the Southern African Development Community); SAfMA Gariep and SAfMA Zambezi were defined by large drainage basins (the Gariep and Zambezi basins, respectively); SAfMA Gorongosa-Marromeu and SAfMA Livelihoods had boundaries that were politically defined.

To understand the implications of spatial heterogeneity, several sub-global assessments used baseline maps of biophysical or basic demographic features to help understand how scenarios unfold differently at different locations. In these cases, the resolution often differs. For example, the simulated landscapes in the Tropical Forest Margins scenarios at the Mekong Region scale were based on 10x10 kilometer gridded input data and processes at this and higher aggregated scales; in contrast, the Tropical Forest Margins–Mae Chaem simulations used a 1x1 kilometer grid as the basis for land use change. The latter landscape may in future be modeled hydrologically on a finer 30x30 meter digital elevation grid.

The issue of spatial resolution and heterogeneity is closely related to decisions about nesting. In practice, developing full scenarios for more than 2 or 3 scales is difficult to envision, but additional detail for some ecosystem services may nevertheless be available through (dis-)aggregation and mapping techniques.

10.5.3 Time Horizons

In general, one human generation was the longest temporal scale considered by stakeholders, and therefore scenarios in the various sub-global assessments usually limited themselves to a 15–25 year time horizon, though a few extended the time period considered to 2050. However, the SAfMA local assessments noted that traditional communities might use much longer time horizons in their planning. Some also included a longer historical time period. For example, the India Urban assessment analyzed the rise and fall of the British Empire over the past centuries. In several assessments, the temporal dimension was not made explicit. ''What if . . . scenarios'' (Coastal BC) and (un)desirable futures (Karnataka village cluster in India Local) are two examples. The aim in these assessments was to reason through the effect of certain policy measures and their ability to deliver desirable futures, rather than to discuss particular time frames. Both these approaches are particularly appealing options when stakeholders are heavily involved in the process; discussions tend to be livelier and results more creative when participants are asked to develop visions for a desirable future or to respond to certain policy measures, without being concerned with questions about exactly when things will happen (Robinson 2003; Kok et al. 2006).

Immediate issues of concern to stakeholders can limit people's perceptions about what is a useful time frame for scenario development. As was stated by the Papua New Guinea assessment in a Knowledge Market session, ''Even at the national level, there is a strange unwillingness on the part of national bureaucrats to think beyond the next five years'' (Colin Filer, personal communication, KM2).

10.5.4 The Linkage between Sub-global and Global Scenarios

Sub-global scenarios often targeted specific user groups and/or addressed specific questions. Therefore, it was not always possible to link the sub-global scenarios to the global scenarios. To harmonize the global and sub-global scenario exercises as much as possible, the following steps were taken:

- Representatives of several sub-global assessments participated in the global scenarios working group.
- Participants of the global scenario team participated at various occasions in meetings of the sub-global assessments, explaining both the preliminary global scenario results and the procedure that was followed in developing the global scenarios.
- At several MA Sub-global Working Group meetings, representatives of the various sub-global assessments were given the opportunity to discuss methodologies with each other. For example, the two Knowledge Markets facilitated the interaction among representatives of most sub-global assessments.

The sub-global assessments had to make practical decisions about how they would make use of the still-evolving global scenarios in their own work. Most groups explicitly opted to focus first on the needs and issues in their sub-global assessments, rather than be overly bound by the directions taken by the global scenarios. This made sense given that sub-global scenarios need to have relevance and explore the options available to decision-makers at sub-global scales.

Nevertheless, exploring commonalities and differences between individual sub-global assessment scenarios and the global scenarios may highlight gaps in logic at either scale or, in some cases, genuine regional differences that are not apparent in more aggregated analyses. These comparisons may also reveal ways in which the global scenarios could be improved to take into account regional differences. Particularly relevant are the sub-global body of information on quantitative, scale-dependent variables such as biodiversity and land degradation. The spatially explicit information gathered by the SAfMA Regional assessment (Biggs et al. 2004) on changes in ecosystem services is a good example.

Different possibilities exist for how scenarios can be nested within each other to create a set of multiscale scenarios. We distinguish five ways to link global and sub-global scenarios:

- The global storylines can be played out at sub-global scales. This would likely be the strongest link, where the global scenarios are downscaled to finer scales, but where the main storylines are similar.
- The global scenarios can be used as boundary conditions for finer scale scenarios, which then develop their own storylines. For example, the trends described for the major driving forces at the global scale can be used for describing the range of variability these drivers exhibit at a regional level.
- The global scenarios can be used to create scenarios about policy and management options being discussed at the sub-global level.
- The underlying assumptions and worldviews played out in the global scenarios can be applied to developing scenarios at sub-global scales.
- Scenarios can be developed independently at global and sub-global levels and can then be compared and mapped against each other afterwards.

These potential methods of linkage were identified in consultation with the sub-global assessments. The fourth and fifth methods of translating worldviews and mapping global and sub-global scenarios onto each other post-hoc were most frequently adopted. It can be expected that with more sub-global assessments developing scenarios, the other methods will be increasingly employed.

Several sub-global assessments (Portugal, PNG, Caribbean Sea, and SAfMA Regional) compared their independently developed scenarios with the four global storylines. The Portugal assessment independently developed scenarios at the national scale, and when compared to the global scenarios, one axis of change was found to be shared in common. Because of this similarity with the global scenarios, the Portugal scenarios were replaced by the four global storylines adapted to Portugal. This replacement also made sense in that it allowed for the quantitative modeling already done in the global scenarios to be applied to the Portugal scenarios work. Furthermore, sub-global use of global scenarios could test methods for scaling down scenarios and provide regional calibration of the global scenarios. The Portugal assessment plans to further downscale the global scenarios to basin and local levels. Sistelo, a local community assessment within the Portugal assessment (Pereira et al. in review), developed independent scenarios that were later integrated into the national scenarios. Most other groups did not find such a close overlap in objectives, key uncertainties, or trends and processes between their scenarios and the MA global scenarios. The PNG assessment noted that the ''MA is itself an activity which belongs to what we call the Globalization scenario'' (Colin Filer, personal communication, KM2).

10.6 Participating in Scenario Development

An important reason for developing scenarios is to construct a more comprehensive analysis of the social-ecological system. Some stakeholders know a tremendous amount about how systems work ecologically as well as socially, and their knowledge is more integrated compared to traditional academic analyses. Most sub-global assessments acknowledged the need for participation but indicated that limited time and budgets put constraints on what could be achieved. However, closer inspection reveals that sub-global assessments differed widely with regard to the reasons for seeking stakeholder participation, who was invited to participate, and the roles they were assigned in the process.

10.6.1 Goals of Participation

Within the context of the MA emphasis on engaging with assessment users, sub-global assessments gave very diverse reasons for seeking stakeholder participation and, after their experiences, revised their perceptions about the value of participation. Some assessments wanted to communicate policy options *to* stakeholders, while others sought to encourage communication among them. For others, the primary interest was to create ''buy in'' to the assessment process. Buy-in refers to the process of first establishing mutual trust among scientists, decision-makers, and other stakeholders, and subsequently establishing a common understanding of the aims of the assessment, the value of participatory processes, and the possible benefits for local stakeholders. For example, the Wisconsin assessment tried to involve indigenous people, which proved difficult due to a history of conflict and lack of trust between the state, non-native local people, and native people. Few assessments employed specific methods to differentiate the perceptions of various local stakeholders on future developments. The focus of the work remained on communication with stakeholders regarding their opinions about the future, without analyzing differences in perceptions among various people or groups.

For simplicity, we synthesized the reasons for seeking stakeholder participation into several main themes. (See Table 10.5). Most of the reasons given were instrumental, that is, aimed at improving the quality of the assessment or at selling its message. However, normative reasons could also have been part of the rationale and some examples of these are listed at the bottom of the table. Leaders of sub-global assessment scenario exercises and stakeholders who actually participated in the exercises probably had different reasons for participating. Of course, the extent to which their various goals were met depended greatly on the methods actually used to engage stakeholders, and which stakeholders actually participated.

10.6.2 Selection of Participants

Unfortunately, most sub-global assessments provided little documentation of the criteria, reasons, and processes by which the participants in scenario work were selected. The sub-global assessments had received detailed guidelines from the MA on the stakeholder selection process (see Bennett and Zurek 2004), emphasizing that stakeholder selection is a crucial step. Stakeholders can strongly influence the

Table 10.5. Reasons for Seeking Participation in Sub-global Assessment Scenario Development Exercises

Instrumental (often expressed)

Persuade and advocate environmental concerns. To raise environmental awareness and increase the ecological knowledge of stakeholders.

Capture an audience. To help achieve buy-in to the assessment process.

Facilitate communication. Discussions around scenarios were used to help explain assessment findings to various stakeholder groups in a flexible form that related easily to their planning and decision-making concerns.

Instrumental (less frequently expressed)

Increase the diversity of perspectives. Scientists have only a small range of experiences and interests. Stakeholder participation helps broaden the perspectives that can be included in the scenarios, making them more realistic and robust.

Improve understanding of social processes. To more accurately capture preferences, values, and possible response behaviors.

Ensure relevance. To ensure scenarios relate to the priorities of managers and decision-makers.

Normative (not usually expressed)

Rights of stakeholders. It should be the right of stakeholders to have their diverse interests represented at the table.

Experts are shortsighted and biased. Experts and facilitators of scenario exercises should not let their biases predetermine the direction and emphasis of scenarios. Participation helps to mitigate such shortsightedness.

outcome of a scenario activity, because they can differ greatly in substantive judgments and/or worldviews.

The SAfMA assessments established a set of advisory committees for governance as well as for types of involvement in the various scenario exercises conducted at different scales. In contrast to the Goulburn Broken Catchment scenario exercise described below, SAfMA found that it was easier to engage stakeholders at the local scale than at the regional scale. Regional decision-makers at the supra-national scale (for example, SADC officials) were particularly difficult to involve.

Sub-global assessments carried out at finer scales (Vilcanota, Bajo Chirripó) placed special emphasis on engaging local and indigenous people, who would experience the effects of scenario outcomes directly. In other sub-global assessments (Sweden SU, Sweden KW, and Western China), the scenarios were very narrowly focused, and therefore assessment teams could target a relatively narrow group of stakeholders for participation. Probably the broadest stakeholder involvement was in SAfMA Livelihoods, SAfMA G-M, and India Local, each of which involved a broad sampling of civil society, including young people in particular.

For various reasons, including budget constraints, the Goulburn Broken Catchment assessment in Australia focused on the participation of key political stakeholders. In this context, representatives from local, state, and commonwealth governments, the Goulburn Broken Catchment Management Authority, community leaders, and a few nongovernmental organizations were targeted. The assessment then made sure that these groups participated in regular workshops, as well as being part of steering and management committees of the assessment (CSIRO Sustainable Ecosystems 2003).

10.6.3 Mechanisms of Participation

Although workshops were the most common tool for defining or refining existing scenarios, a wide range of mechanisms were employed to engage stakeholders in the scenario-building process. Some sub-global assessments that were still in the scenario planning process at the time of writing (for example, São Paulo) intended to employ more innovative facilitation methods to improve engagement of participants, including role-playing games, computer games, and citizens' juries (also the main method used in the Goulburn Broken Catchment study). Most sub-global assessment groups acknowledged that workshops with stakeholders are expensive, and take effort and skill to prepare and implement. The number and size of these activities were clearly constrained by time and financial resources in most sub-global assessments. The Caribbean Sea assessment followed stakeholder workshops with expert group meetings to build multiscale scenarios.

Interview techniques were also employed (India Local, Sinai), as well as a range of other more informal meetings, mostly in the early phases of the assessment. In India Local, researchers were stationed in the villages, thus effectively monitoring and interviewing the stakeholders for longer periods of time.

Within the Wisconsin assessment, questionnaires were distributed and a website was maintained for public discussion and feedback. Individual interviews to discuss the scenarios were conducted with leaders of local government, Native American tribes, and lake associations. People in the region were surveyed randomly to gather their opinions of the scenarios. A computer game for managing the region was developed and tested with small groups of stakeholders; eventually the computer game will be used in workshops to revise the scenarios both qualitatively and quantitatively. The scenarios have been widely covered in the media. Although this project began as a largely expert-driven exercise, it has matured over time into providing more and more avenues for public participation. As a result, the scenarios are likely to be iteratively refined, as acknowledged at the end of the first phase by the authors (Peterson et al. 2003a).

10.6.4 Roles of Participants

Participation in scenario-building activities ranged from passive roles, where stakeholders served simply as an audience, to highly interactive experiences, where participants were called upon to directly shape, design, and validate the scenarios. The ability to have direct input into the creation of scenarios, in addition to scenario validation, represents a more fully participatory approach. Coastal BC, India Local, India Urban, Tropical Forest Margins–Cameroon, Wisconsin, SAfMA Livelihoods, SAfMA G-M, and Portugal, all employed workshops at some stage of the assessment to gather valuable input on scenario design, as well as to review the scenarios.

10.6.5 Problems Encountered in Participation

Although most sub-global assessments lack documented information on stakeholder involvement, the two Knowledge

Markets provided many insights on some of the problems encountered in the scenario-building process. It is difficult to assess the underlying reasons for the problems that were mentioned, but a few insights can be learned from these discussions.

Sub-global assessment teams acknowledged that the very nature of stakeholder involvement is a creative and stimulating process, although the outputs can be highly unpredictable in terms of their value and usefulness to scenario activities. The main conclusion is that involving stakeholders, especially through workshops and meetings, is a very slow process that is resource-intensive. Other problems mentioned included:

- initially not all relevant stakeholders were selected (Caribbean Sea);
- serious cultural obstacles to effective scenario-building (PNG);
- stakeholders' unfamiliarity with radically different technologies (India Local);
- exogenous driving forces not of interest to participating communities (Trinidad);
- stakeholders have limited access to, and/or limited understanding of, information on processes at other scales (Caribbean Sea, India Local); and
- preoccupation with tangible outputs (Portugal).

These problems highlight the necessity of careful preparation before workshops and other information-gathering exercises.

10.7 Communication in Sub-global Scenarios

The issues of communication and participation are closely intertwined. If communication is viewed as advertising, then it is largely one-way, but if the aim is genuine and interested dialogue, then the possibilities of more symmetrical two-way exchanges, among stakeholder groups or between scientists and policy-makers, become real.

The development of scenarios involves two distinct forms of communication. One is the process of communication between scientists and other stakeholders that enables the scientists and other stakeholders to formulate alternative storylines. The other is the process by which the scientists then communicate these alternatives to an audience. This latter form of communication includes, but may not be restricted to, the stakeholders involved in the first process. The first process is communication *for* scenarios; the second process is communication *of* scenarios. The first process was addressed in the preceding section on participation, though primarily with an emphasis on the question of who participates, rather than the form of communication through which they participate. These two forms of communication—among experts and between experts and others—theoretically could be connected in an on-going process of dialogue by which scenarios are continually modified as a result of feedback from the stakeholders who participate in the initial construction, but this may not be feasible in practice because of resource constraints.

10.7.1 Communication Strategies

In relation to strategies adopted, the sub-global assessments can be divided into four groups:

- those that adopted specific forms of communication for both the development and dissemination of scenarios, and separated the communication of scenarios from the communication of the overall results of the assessment in order to address the needs and interests of specific user groups. Examples include the SAfMA local assessments and the Tropical Forest Margins assessments;
- those that used specific forms of communication with relevant stakeholders in the development of their scenarios, but did not separate the communication of these scenarios from the overall results of their assessments. The majority of sub-global assessments fall into this category;
- those that developed their initial scenarios without the active participation of relevant stakeholders, but still propose to develop distinctive forms of communication for the modification and dissemination of these scenarios. The PNG assessment seems to be the only one in this category (see Box 10.3);
- those that made little or no use of scenarios in their assessment—mostly because of budget constraints—and have not therefore adopted any specific forms of communication for this purpose. A good example of a sub-global assessment that did not have the resources to invest in communication was Coastal BC, which intended to use the interactive computer game QUEST (Tansey et al. 2002).

A minimal communication strategy would be one that embeds the results of scenario development in written reports addressed to an audience of scientists and policy-makers. Most assessments proposed to do this. Some went further than this, by communicating the results of the assessment (including scenarios) in a form that was suitable for ''consumption'' by other user groups, such as schoolchildren or illiterate members of local communities. The rest of this chapter focuses primarily on those cases in which scenarios have been, or will be, treated as a separate output of the assessment process.

10.7.2 Scenarios in Policy Dialogues

A number of sub-global assessments (for example, SAfMA, Tropical Forest Margins–Pan-Tropics, Western China) employed similar modes of communication with policy-makers and/or decision-makers at the beginning of their scenarios exercises and at the end when reporting the results. Reporting may be directed either to the same group of stakeholders involved in the original exercise, or to other groups at different levels in the policy-making process. This type of iterative communication normally involves a series of workshops or seminars in which scenarios are designed or analyzed with the aid of computer technology. For example, the Caribbean Sea scenarios will be used to guide the deliberations of ministers and senior officials engaged in the process of negotiating an intergovernmental management regime.

BOX 10.3

Obstacles to Communication: Papua New Guinea

The first (national) phase of the PNG assessment did not engage in a process of communication for scenario development, partly because of the limited budget allocated for work in this phase and partly because some relevant scenarios had already been developed in previous forms of policy dialogue at the national scale. These earlier scenarios were modified by the scientists engaged in the assessment in order to take account both of the global scenarios developed by the MA Scenarios Working Group and of the changing tenor of national debate about the country's political, economic, and environmental future, as reflected in the pages of the national press.

The scenarios developed in the national phase of the assessment will be used as an input to the communication process for further scenario development at the provincial and community scales in the second phase of the assessment. In this second phase, various communication techniques will be applied to the development of models and storylines at the national and community scales, and then to the task of communicating scenarios through an education and outreach program.

The outreach program is part of the community-based marine conservation project in which the assessment is embedded. The choice of techniques for communication will depend partly on the lessons already learned from other sub-global assessments and partly on the lessons learned from experiments with similar forms of communication in the southwest Pacific region. A well-known community theater group (based in Vanuatu) has produced a film about the effects of one driver (increasing population pressure) on ecosystem services and human well-being in one (imaginary) coastal local community. The national assessment report includes a brief evaluation of that process because of its potential applicability in future assessments.

PNG also includes the interesting observation that popular or community reactions to the process of scenario construction may be influenced, in some areas, by the prevalence of millenarian religious beliefs, especially when people are invited to include uncertainties or surprises or catastrophes in their storylines. This point underlines the importance of paying careful attention to the cultural context when designing a communication strategy for the development and dissemination of scenarios.

The Tropical Forest Margins assessments illustrate the way in which this type of communication is varied to accommodate the needs and interests of decision-makers at different levels in a policy process. For example, at the pan-tropic level, scenarios were developed to analyze the implications of biodiversity loss on hydrological functions. Constant iteration with a World Bank expert helped to delineate the focus of the results in order to effectively inform policy-makers. At the end of the project, the results were presented in a one-day policy seminar at the World Bank and are available at: http://www.asb.cgiar.org/BNPP/phase2/bnpp_phase2_general.htm. At the regional scale in Brazil, an economic equilibrium model was used to test the effects of devaluation on forest area in the Brazilian Amazon. The published results were mainly targeted at the regional government, as well as the national and international scientific communities. At the basin scale, Tropical Forest Margins–Mae Chaem tested different implications of hydrological functions by applying expert-driven scenarios; the results were communicated at the World Bank seminar, but also will be part of a wider strategy to translate the results to policy-makers throughout Southeast Asia. In Tropical Forest Margins–Western Brazil, data obtained at the local level were used to inform farm-level ''bioeconomic models'' in which the effects of different mixes of technological innovations were tested at different time horizons. The results were communicated to policy-makers through EMBRAPA, a Brazilian institute that is one of the partners in the Tropical Forest Margins consortium.

Stakeholder workshops and other types of face-to-face communication were used to disseminate the overall results of the SAfMA assessments at a number of different scales. SAfMA G-M presented verbal descriptions of its scenarios, first to local communities to elicit their responses (what they would do in each scenario) and then to local policy-makers to also elicit responses (what policies should be put in place). According to Tim Lynam (personal communication), who participated in these exercises, the community presentations were very successful and their responses were used in the assessment, whereas the policy presentations were not as successful.

10.7.3 Storylines for a Wider Audience

Stories about the future can be the most interesting and exciting way of communicating the results of an assessment to an audience that does not consist exclusively of scientists and policy-makers. However, there could be some incompatibility between the divergent needs of establishing the scientific credibility of alternative scenarios and communicating these scenarios effectively to a wider audience.

The SAfMA assessments followed the common practice of incorporating the analysis of scenarios into written materials that represented the overall results for the benefit of the different users represented on the advisory committees. This assessment went further than most in producing different types of documentation, from brochures to scientific journal articles, in order to address the needs and interests of different user groups, and hence to convince them of the usefulness of the assessment. However, while the communications strategy was thought to have been appropriate for the needs of policy-makers and planners in the public sector, it was recognized that communication with the general public was more problematic.

San Pedro de Atacama was the only assessment that developed specific media for communicating scenarios to schoolchildren. The assessment devised a process of familiarizing local children with the ecosystem that was being assessed, partly by engaging indigenous elders to provide informal lessons on recent ecosystem history. This exercise in oral history was expected to provide the basis for constructing plausible futures. In India Local, schoolchildren were also engaged in the process of data collection and monitoring, although the assessment did not include a separate communication of scenarios. PNG also used specific

media for communication with schoolchildren, but again not in the context of developing scenarios. In the Wisconsin assessment, booklet cartoon maps and illustrations were used to communicate the scenarios, though not necessarily only to young readers.

10.7.4 Spatial Representations of Scenarios

Spatial mapping or modeling techniques may be used as a distinctive form of communication in the development and dissemination of scenarios, but most sub-global assessments appear to have treated these as one aspect of the policy dialogue with a sophisticated audience of scientists and policy-makers, rather than a technique for securing popular participation or understanding.

At the local level, the Tropical Forest Margins–Cameroon assessment had villagers actively participating in the formulation of scenarios, using historic transects and creating graphics of the landscape futures across time. This was a form of participatory rural appraisal, which has been widely used in developing countries. In this particular case, the results were inconsistent with the scientific research findings on the investment strategies of local farmers.

In the case of Coastal BC, various stakeholders proposed emphasizing the use of mapping techniques to communicate the scenarios, as well as to record baseline data about the condition of ecosystem services and human well-being. Stakeholders asserted that mapping products would allow the users, including members of indigenous communities, to grasp the spatial and temporal scope of consequences emerging from their decisions. Investment in clear and effective techniques for the communication of scenarios was also thought to be a useful way of connecting the scientific and policy communities involved with the assessment. The application of these mapping techniques proved to be difficult, firstly because of technical problems with the software chosen for this purpose, and secondly because the methodology was not clearly understood by some of the stakeholders engaged in the initial process of communication. In other contexts, there might have been some resistance from indigenous communities to the idea of mapping their resources and placing these maps in the public domain, but this does not seem to have been an important obstacle in this case.

10.7.5 Community Theater and Video Techniques

The representation of scenarios by means of theatrical performances or film and video recordings is almost certainly the most powerful way of communicating ''plausible futures'' to a popular audience, but the human and financial resources available to the sub-global assessments limited the use of such techniques.

In the SAfMA Livelihoods assessment, a series of short plays representing alternative scenarios were performed before an audience drawn from one of the communities involved in the assessment process. Members of the community had some opportunity to participate in the process of scripting these plays before their performance, but had not been directly involved in the initial process of scenario development, which was based on communications with stakeholders at a higher level.

In this case, the communication of scenarios managed to accomplish the difficult task of dramatizing the content of a scientific report, but was essentially a feedback mechanism added on to the end of the assessment process. Like some other stakeholders in the assessment process, the audience was left to wonder what would happen after the scenarios had been communicated, but had at least been convinced that their own future was uncertain and that they could play a role in shaping it.

For SAfMA Livelihoods, the choice of media was dictated by the low levels of literacy in the community, and by the observation that local people were more likely to engage with messages conveyed through live performance than those conveyed through film. This still leaves open the question of how best to communicate scenarios to multiple communities living in similar circumstances, given the high transaction costs involved in the medium of community theater.

10.8 Findings of the Sub-Global Scenarios

Most of this chapter has focused on how the sub-global scenarios were developed. This section considers the findings they produced. It is an analysis of a selection of the resulting scenarios, concentrating on the main driving forces identified during scenario development, key processes described, the main ecosystem services included, and a cross-scale comparison of the scenarios results. The section first describes a few examples of how uncertainties and ecosystem services were treated, comparing among sub-global scenario findings. It then analyzes the scenario findings with respect to geographical scale and examines whether scale had any influence on the interpretation of scenario outcomes.

This section focuses only on those scenario exercises that were well advanced in at least their first iteration and that had therefore started to draw initial conclusions at the time of writing. The comparison mainly draws from the multi-scale SAfMA assessment, Caribbean Sea, India Local, and the first draft of scenarios from the Bajo Chirripó and Portugal assessments. It should be noted well that when more results become available, the conclusions drawn here might change slightly.

10.8.1 Commonalties among Scenario Findings

A comparison of similarities among major driving forces of change, key ecosystem services, and processes described by the sub-global scenarios can help to enhance understanding of how these forces work and interact. While the scenario exercises in many cases differed in their conclusions, a few common themes emerged. Governance was the one driving force that surfaced in almost all the scenario exercises considered. Biodiversity was another issue that a number of scenarios addressed because it relates to a number of ecosystem services.

10.8.1.1 Key Uncertainties: Governance

Governance issues were the only major uncertainty that surfaced in almost all scenario exercises considered. The nature of different governance regimes was used by many assessments as a major driving force to differentiate between scenario trajectories. In the multiscale SAfMA sub-global assessment, where the scenarios at different scales were developed independently, governance was identified as a key bifurcation at all scales. Social equity and the distribution of wealth was the second major axis of uncertainty in SAfMA.

In the scenarios built by the Caribbean Sea assessment, the main bifurcation that emerged centered on the issue of economic diversification: continued reliance on tourism as the main source of income for the region versus economic diversification to increase the resilience of economic systems. The issue of economic diversification in the Caribbean was strongly connected to a set of governance issues, such as regional cooperation, trade negotiations, and institution building.

The first set of national scenarios developed by the Portugal assessment identified the attitude of society toward the environment and its understanding of environmental change as one of the main driving forces. Here, an environmentally friendly attitude was translated into lifestyles and governance systems and institutions that try to find a balance between environmental protection and development. The second main driving force for these scenarios, land use measures and agricultural practices, were seen to be influenced by institutional structures and polices such as the Common Agricultural Policy of the European Union.

The draft scenarios for Bajo Chirripó also used governance as one major factor affecting the future of the indigenous communities in the area. Clarifying their rights under a new law that was discussed with the Costa Rican government at the time of the scenario exercise was described as one of the main bifurcation points for the future.

Besides governance, other factors, such as climate change at the global level or land use change at more local/regional levels, were also considered in various sub-global assessments. However, there was a much higher degree of variability among the other drivers considered by the sub-global assessments.

10.8.1.2 Key Ecosystem Services

The specific ecosystem services addressed varied widely among the various sub-global assessments. Table 10.6 lists some ecosystem services that were mentioned as being important. Two services immediately stand out: biodiversity and water quantity and quality. The prospects for biodiversity were clearly an important issue in many sub-global scenarios, being explicitly mentioned by five out of the eight sub-global assessments examined here. Water quantity and quality was also an important service, mentioned by six out of eight assessments. However, the water issue covered a large variety of different aspects including flooding, drought, irrigation, and salinity, drawing a picture that is less coherent than for biodiversity. A number of services were mentioned by only one or two sub-global assessments, including soil protection, tourism, and landscape aesthetics.

Table 10.6. Key Ecosystem Services Addressed in the Scenarios of Various Sub-global Assessments

Ecosystem Service	Sub-global Assessment
Biodiversity (pollination, pest control, genetic resources, habitat regeneration)	SAfMA, Caribbean Sea, Portugal, Bajo Chirripó, India Local
Water quality and quantity	Goulburn-Broken Catchment, Wisconsin, SAfMA, Portugal, Bajo Chirripó, San Pedro de Atacama
Soil protection	Portugal
Landscape aesthetics	Wisconsin, Portugal, San Pedro de Atacama
Recreation/Tourism	San Pedro de Atacama, Caribbean Sea

10.8.1.2.1 Biodiversity

Introducing policy and legal measures to protect biodiversity was seen in some regions as having a major impact on how biodiversity will be used in the future. Draft scenarios in both Portugal and India Local described this kind of response option to current biodiversity decline as major decision points. In Portugal, a move toward payments for environmental services to farmers due to changes in the EU CAP was seen as having a positive impact on biodiversity. In India, the introduction of a National Biodiversity Act opened up new prospects for biodiversity conservation, although it was recognized that the measure needed to be coupled with strengthening the institutional capacities for enforcing and monitoring the act and for collecting and managing data. At the same time resolving conflicts between developmental and biodiversity conservation goals at the local level were seen as an important challenge in the future.

Climate change was seen to hold significant uncertainties for biodiversity in a number of scenario exercises. Changing sea temperatures in the Caribbean are likely to influence primary production and may have surprising effects on populations of fish, corals, and other keystone species. Climate change is also an important stressor for southern African ecosystems. But even without accounting for its impacts, in all SAfMA Regional scenarios, biodiversity will decline over the next three decades, although the rate of decline and expected level of stabilization differ depending on the scenario assumptions.

Technological development was described in Caribbean Sea as having the potential to change the regional status quo for biodiversity in novel and possibly unexpected ways. Better bioprospecting technologies could lead to increased pharmaceutical involvement in several poorer regions of the world. In the Caribbean, the implications of better fishing technologies and fish-tracking devices, such as allowing greater and more selective exploitation of fish stocks for food, were explored. Improvements in monitoring and enforcement technology make it easier to manage fish stocks sustainably.

10.8.1.2.2 Water

Water quality and quantity are other examples of ecosystem services addressed explicitly in many sub-global assessments. While in Wisconsin, for example, water quality was of particular importance, the San Pedro de Atacama and the SAfMA scenario exercises focused mainly on water availability, with each identifying a threat to the availability of water resources in their respective areas.

These are but examples of the variety of ecosystem services that were considered. Even when categorized under the same common denominator, the focus was often different in different places, while in most sub-global assessments at least one ecosystem service was unique. The list of ecosystem services will undoubtedly grow as more sub-global assessments produce results, but it is also anticipated that most sub-global scenario exercises will include common ecosystem services such as water, biodiversity and possibly tourism.

10.8.2 Comparing Findings across Scales

10.8.2.1 Differences in Scenarios across Scales

Table 10.7 shows how three sub-global scenarios exercises (SAfMA, Caribbean Sea, and Portugal) can be mapped onto the MA global scenarios exercises based on the common elements among them. The process of how the specific scenarios were developed differed between the exercises; however, they all contain specific aspects that also occur in the global scenarios. These include either common basic storyline elements across the exercises (that appear for example in both the global MA scenarios and the Portugal scenarios) or similar assumptions and ideas (for example, a globalized versus a fragmented world), such as in the global MA, SAfMA, and Caribbean Sea scenarios. Our analysis shows that a number of common themes can be found across scales. These themes could be interpreted and played out differently at each geographical level, as the comparison between the Caribbean Sea and the MA global scenarios demonstrates. Both exercises used the degree of interconnectedness with the world as one of the main differences between the portrayed future worlds.

10.8.2.2 Differences in Perceptions across Scales

One interesting outcome of comparing the scenarios across scales is that the analysis reveals how the interpretation of scenario outcomes by stakeholders can differ across scales. What is seen as a beneficial outcome by stakeholders at one scale can be interpreted differently by stakeholders at another scale.

The Portugal assessment describes this tension in a comparison of its national and local scenarios: One local scenario in Portugal is characterized by the abandonment of agricultural fields and rural outmigration. Agricultural terraces are replaced by oak forests, with the loss of local provisioning services but a likely improvement in biodiversity. For local policy-makers this land abandonment scenario is undesirable. However, in the national and global context, the scenario could be part of a Global Orchestration type scenario (described in Appendix 10.1), which is viewed by policymakers at these coarser scales as having the highest direct benefits to human well-being.

The Caribbean Sea scenarios demonstrate this difference in scenario interpretations as well. The Caribbean region is considered particularly vulnerable to external forces because of its current and historically high reliance on international markets and capital, and the effects of economies of scale on small islands and developing states. While a well-connected world that emphasizes the equitable distribution of wealth may hold benefits for poorer regions of the world, it also holds substantial risks. For the Caribbean region, which is already highly connected to international markets and is particularly dependent on international tourism, a Global Orchestration-type scenario would most likely result in further dependence on these external markets. A change in

Table 10.7. Cross-mapping of SAfMA, Caribbean Sea, and Portugal Scenarios onto the MA Global Scenarios

	SAfMA Scenarios				Caribbean Sea Scenarios	Portugal Scenarios		
MA Global Scenarios	**Regional**	**Gariep**	**Livelihoods**	**Gorongosa-Marromeu**		**National (first phase)**	**National (second phase)**	**Sistelo (local)**
Global Orchestration	African Partnership	Policy Reform	Betterment	Devolution	Neo-plantation-Economy	Evolution of Continuity	*Global Orchestration* (downscaled)	Abandonment
		Market Forces	Green Engineering	Patronage				
Techno Garden					Quality over Quantity	Celestial Portugal	*Techno Garden* (downscaled)	
Adapting Mosaic	African Patchwork	Local Resources	Stagnation		Diversify Together	Bucolic Portugal	*Adapting Mosaic* (downscaled)	Rejuvenation
Order from Strength		Fortress World			Growing Asymmetries	Portugal at its Worst	*Order from Strength* (downscaled)	

tourism activities for any reason, and particularly if it were abrupt, would have significant negative impacts on the region's economy.

Another example can be taken from SAfMA. The multiscale structure of the SAfMA assessments showed that certain responses or developments at coarser scales are experienced as surprises or shocks at local scales (for example, if mega parks and large irrigation schemes are implemented without adequate local stakeholder participation and consideration of impacts). The SAfMA regional and local scale scenarios also suggest that general trends in ecosystem services at the regional and basin-scale may be reversed in particular local situations. The SAfMA results are also interesting with respect to comparing global and regional interpretations of scenario outcomes. The greatest direct benefits to human well-being are generally expected under scenarios corresponding to the Global Orchestration scenario. However, a key uncertainty in southern Africa is the degree of social equity that would prevail under this scenario. While economies are expected to strengthen, the degree to which the benefits of economic growth are distributed within society is seen as an important bifurcation point, as evidenced by the different variations of the Global Orchestration scenario in SAfMA Regional. Without specific emphasis on policies that ensure social equity, it appears unlikely that economic growth will hold substantial benefits for the poor. The SAfMA results here reinforce one of the messages of the Global Orchestration scenario.

These examples show that the comparison of scenario interpretations across scales can reveal useful insights for developing response options for different stakeholders under the various scenarios developed. They show where differences between stakeholder priorities or worldviews lie, and can therefore be used to analyze potential areas of conflict between them.

10.8.3 Summing Up: The Importance of Stakeholders

The comparison of findings across the sub-global scenario exercises reveals more differences than commonalities in specific results. Given the high degree of variability among the sub-global assessments that were considered here, this was to be expected. Nevertheless a number of emerging common themes can be used to ground-truth coarser scale scenarios. In particular, the importance of governance as a main driver in all sub-global assessments should be checked against assumptions in the global storylines.

More importantly, the set of scenarios for which results were available showed that each strategy has winners and losers, which vary depending on the scale examined. Scenarios that appear beneficial at the national scale may hold substantial losses and threats for certain communities at finer scales. Identification of winners and losers in each scenario is an important step in guiding future responses. The inclusion of stakeholders in scenario development and validation processes helps make explicit the circumstances under which winners and losers emerge. The comparison of scenario findings across scales also demonstrates that scenario interpretations differ across scales. In the context of the purposes and methods employed to develop scenarios, directly involving end-users and stakeholders in the process, these conclusions suggest a need for more comprehensive engagement with users and a more systematic analysis of their perceptions.

10.9 Conclusions and Recommendations for Future Assessments

10.9.1 Strength in Diversity

The MA sub-global assessments comprise a unique collection of scenario-building experiences covering several continents and a wide variety of local, national, and regional contexts. The most outstanding feature of this collection is the diversity of goals and of approaches to building, refining, and communicating scenarios. At the same time, the various assessment groups have kept the goals of assessing ecosystems services and human well-being largely in focus. ***The lesson is that there is no single clearly superior way to conduct scenarios.*** As noted, constructing storylines using one or two main uncertainties as axes worked well for some assessments, but inhibited creativity for some others. Prospective scenario-builders and users can reflect upon a list of questions, such as the ones shown in Figure 10.1, to guide their processes. This final section highlights some important points not fully considered in previous sections.

10.9.2 Lessons Learned

The most significant strength of the entire endeavor is the common methodology that links all sub-global assessments. Given the variety of assessments, important conclusions on how best to construct scenarios can be drawn. Already discussed were recommendations on how linking global and sub-global scenarios could be made successful, and when there are good reasons not to attempt a complete link. Similar recommendations follow in this section for other methodological aspects, such as stakeholder involvement. Engaging local stakeholders is another important strength of most sub-global assessments. In particular, the use of participatory approaches, and thus the incorporation of key decision-makers in the process, was attempted in most assessments.

A problem encountered by all assessments was the relatively poor link between the various sub-global scales. All assessments recognized the importance of nesting across scales, and all devoted some attention to key factors at different scales. However, few assessments focused on cross-scale interactions and feedbacks, with the notable exceptions of SAfMA Regional and planned work in Portugal. In most assessments, the emphasis was at the level of decision-making, in other words at the political or social scale, rather than the ecological scale (scales of time and space). It has not been possible in this chapter to cover all aspects of political/social scale and ecological scale, and it is expected that the two will not always coincide.

10.9.2.1 Integrating Scenarios with other Assessment Components

The degree to which the scenario-based activities in the assessments were linked to efforts to assess conditions and trends, or explore responses, varied greatly among sub-global assessments. Integration was excellent for a number of sub-global assessments, such as San Pedro de Atacama (management options) and SAfMA (condition and trends), but could have been improved for many others. A number of sub-global assessments, including SAfMA Regional, acknowledged specifically that scenarios were a relatively small part of the assessment. Some assessments regarded scenarios primarily as a useful *tool* to communicate with local decision-makers rather than as a result in their own right. Elevating the importance of scenario development could have consequences for methods employed, such as stakeholder selection, scale selection, and dealing with uncertainties.

Nevertheless, the use of narrative scenarios developed through participatory methods is relatively new to the scientific world, and therefore full realization of the potential gains should not yet be expected. It should be noted that scenario development is being assigned increasing importance in the process of testing the robustness of policy measures, and was prominent in many sub-global assessments (including Portugal, SAfMA Regional, and Sweden). The connection between this type of scenario analysis and other analyses, however, is still rather weak. A method to link qualitative stories to quantitative models is clearly needed, although some progress is being made in the sub-global assessments in Western China, Downstream Mekong, and Laguna Lake Basin. More attempts and examples are needed to convince future sub-global assessments that scenario development extends the quantitative or forecasting methods in a positive and meaningful way, and that it also helps decision-makers to think, talk, plan, and act imaginatively in pursuit of a more sustainable society.

10.9.2.2 Improving the Link between Global and Sub-global Scenarios

The greatest challenge in trying to link global and sub-global scenarios is increasing understanding in many (very local) assessments of how such large-scale developments can be translated to the local level. There are many solutions to bridge this gap between global and local. Most of them involve a ''translation'' of the global scenarios to make them more applicable to the local situation:

- *Translate ''facts'' to ''feelings.''* Local stakeholders will be less overwhelmed by global developments if they are not presented as facts but as underlying assumptions and (changes in) worldviews. For instance, the presentation of the Techno Garden scenario could focus more on ''society's ability to invent'' (see Appendix 10.1) and less on technical solutions that are imposed on a reactive society.
- *Translate all multiscale aspects*. Developments have to be presented to local stakeholders not only for a smaller geographical region, but also for shorter time scales and for shorter human decision-making scales. Local stakeholders do not relate as easily to the effects of global warming, as they would to three consecutive years of drought.

The need for translation relates directly to the primary goal for which scenarios are constructed. At the global level, scenarios are mainly used as a communication tool and to inform decision-making on important future trends and uncertainties. At the local level, scenarios have been utilized more as a direct tool for engaging people from different sectors of society, and leveraging expertise in decision-making processes. In general, the more local the scale, the more scenarios become a tool for empowerment.

The above implies that the challenge lies both with the sub-global assessments that need to make an effort to downscale global storylines, and with the global assessments that could improve the manner in which their scenarios are presented. Scenarios developed both at global and sub-global scales could have benefited from some additional iteration. Only with these methodological efforts can we begin to link the rich variety of local and regional stories and global developments.

Despite the complexity that these mismatches introduce and the fact that ''multiscale'' considerations are not always important for each sub-global assessment, the MA effort has stimulated renewed interest in the potential for multiscale scenario development. It potentially has much greater local policy relevance than most previous global environmental assessments.

10.9.2.3 Regional Diversity, Multiple Scales, and Ecology

The diversity of local and regional scenarios being developed by the sub-global assessments represents a major challenge to the global assessment community and it may often be difficult, and even counter-productive, to tightly constrain (or link) scenarios developed at these sub-global levels with those at higher or lower levels. On the other hand, checking for inconsistencies in major assumptions (''discordances across scale'') may help interpret regional variation and improve scenarios at both global and sub-global scales. How much attention needs to be paid to these cross-scale concerns ultimately depends on how inconsistent the key processes of change are for the particular ecosystem services assessed.

In most sub-global assessments, the interactions between ecosystems, their services, and human well-being were rather poorly documented, and their incorporation in the scenarios was relatively insignificant. There are difficult decisions to be made in the design of scenario exercises, between focusing on a few services that can well be understood and trying to realize a better appreciation of interaction between a wider range of services in a more comprehensive, but less detailed assessment. The currently advocated methods of developing holistic, integrated, participatory scenarios might not be the best to address the objective of the scenario exercises. When the main objective of developing scenarios is direct decision support, and the uncertainties and possible futures are pre-defined, complex participatory processes may, in particular, be unnecessary.

10.9.2.4 Concluding Remarks

There are four main conclusions from this chapter, based on the unique source of information that the large and growing number of sub-global assessment scenarios represent:

- Of all the approaches to conducting scenarios, none is clearly superior to the others.
- Sub-global scenarios allow for the critical evaluation of local variations that cannot be properly assessed at the global scale alone.
- Scenarios developed at global and sub-global scales could have benefited from additional iteration and interaction across scales. Only with additional methodological efforts can we begin to link the rich variety of sub-global and global scenarios.
- In relation to global assessment frameworks, the MA is unusual in its emphasis on ecology. Even so, future scenario activities should pay even greater attention to ecological processes.

Finally, we must acknowledge that the level of skill in conducting scenario exercises and then integrating these with assessments of conditions and trends, and response options, is still growing. The sub-global assessments represent a heterogeneous collection of approaches, focal issues, and scales, which is an encouraging start for much more experimentation with scenarios and related future-exploring methods.

Appendix 10.1. Summary of Global Scenarios in the Millennium Ecosystem Assessment

The *Global Orchestration* scenario depicts a globally connected society in which policy reforms that focus on global trade and economic liberalization are used to reshape economies and governance, emphasizing the creation of markets that allow equitable participation and provide equitable access to goods and services. These policies, in combination with large investments in global public health and the improvement of education worldwide, generally succeed in promoting economic expansion and lifting many people out of poverty into an expanding global middle class. Supranational institutions in this globalized scenario are well placed to deal with global environmental problems such as climate change and fisheries decline. However, the reactive approach to ecosystem management makes people vulnerable to surprises arising from delayed action. While the focus is on improving the well-being of all people, environmental problems that threaten human well-being are only considered after they become apparent. Growing economies, expansion of education, and growth of the middle class lead to demands for cleaner cities, less pollution, and a more beautiful environment. Rising income levels bring about changes in global consumption patterns, boosting demand for ecosystem services, including agricultural products such as meat, fish, and vegetables. Growing demand for these services leads to declines in other ones, as forests are converted into cropped area and pasture and the services they formerly provided decline. The problems related to increasing food production, such as loss of wildlands, are not apparent to most people who live in urban areas. They therefore receive only limited attention. Global economic expansion expropriates or degrades many of the ecosystem services poor people once depended on for survival. While economic growth more than compensates for these losses in some regions by increasing the ability to find substitutes for particular ecosystem services, in many other places, it does not. An increasing number of people are affected by the loss of basic ecosystem services essential for human life. While risks seem manageable in some places, in other places there are sudden, unexpected losses as ecosystems cross thresholds and degrade irreversibly. Loss of potable water supplies, crop failures, floods, species invasions, and outbreaks of environmental pathogens increase in frequency. The expansion of abrupt, unpredictable changes in ecosystems, many with harmful effects on increasingly large numbers of people, is the key challenge facing managers of ecosystem services.

The *Order from Strength* scenario represents a regionalized and fragmented world that is concerned with security and protection, emphasizes primarily regional markets, and pays little attention to common goods. Nations see looking after their own interests as the best defense against economic insecurity, and the movement of goods, people, and information is strongly regulated and policed. The role of government expands as oil companies, water utilities, and other strategic businesses are either nationalized or subjected to more state oversight. Trade is restricted, large amounts of money are invested in security systems, and technological change slows due to restrictions on the flow of goods and information. Regionalization exacerbates global inequality. Treaties on global climate change, international fisheries, and trade in endangered species are only weakly and haphazardly implemented, resulting in degradation of the global commons. Local problems often go unresolved, but major problems are sometimes handled by rapid disaster relief to at least temporarily resolve the immediate crisis. Many powerful countries cope with local problems by shifting burdens to other, less powerful ones, increasing the gap between rich and poor. In particular, natural resource–intensive industries are moved from wealthier nations to poorer, less powerful ones. Inequality increases considerably within countries as well. Ecosystem services become more vulnerable, fragile, and variable in *Order from Strength*. For example, parks and reserves exist within fixed boundaries, but climate changes around them, leading to the unintended extirpation of many species. Conditions for crops are often suboptimal, and the ability of societies to import alternative foods is diminished by trade barriers. As a result, there are frequent shortages of food and water, particularly in poor regions. Low levels of trade tend to restrict the number of invasions by exotic species; ecosystems are less resilient, however, and invaders are therefore more often successful when they arrive.

In the *Adapting Mosaic* scenario, regional watershed-scale ecosystems are the focus of political and economic activity. This scenario sees the rise of local ecosystem management strategies and the strengthening of local institutions. Investments in human and social capital are geared toward im-

proving knowledge about ecosystem functioning and management, which results in a better understanding of resilience, fragility, and local flexibility of ecosystems. There is optimism that we can learn, but humility about preparing for surprises and about our ability to know everything about managing ecosystems. There is also great variation among nations and regions in styles of governance, including management of ecosystem services. Some regions explore actively adaptive management, investigating alternatives through experimentation. Others use bureaucratically rigid methods to optimize ecosystem performance. Great diversity exists in the outcome of these approaches: some areas thrive, while others develop severe inequality or experience ecological degradation. Initially, trade barriers for goods and products are increased, but barriers for information nearly disappear (for those who are motivated to use them) due to improving communication technologies and rapidly decreasing costs of access to information. Eventually, the focus on local governance leads to failures in managing the global commons. Problems like climate change, marine fisheries, and pollution grow worse, and global environmental problems intensify. Communities slowly realize that they cannot manage their local areas because global and regional problems are infringing on them, and they begin to develop networks among communities, regions, and even nations to better manage the global commons. Solutions that were effective locally are adopted among networks. These networks of regional successes are especially common in situations where there are mutually beneficial opportunities for coordination, such as along river valleys. Sharing good solutions and discarding poor ones eventually improves approaches to a variety of social and environmental problems, ranging from urban poverty to agricultural water pollution. As more knowledge is collected from successes and failures, provision of many services improves.

The *TechnoGarden* scenario depicts a globally connected world relying strongly on technology and highly managed, often engineered ecosystems to deliver ecosystem services. Overall efficiency of ecosystem service provision improves, but it is shadowed by the risks inherent in large-scale humanmade solutions and rigid control of ecosystems. Technology and market-oriented institutional reform are used to achieve solutions to environmental problems. These solutions are designed to benefit both the economy and the environment. These changes co-develop with the expansion of property rights to ecosystem services, such as requiring people to pay for pollution they create or paying people for providing key ecosystem services through actions such as preservation of key watersheds. Interest in maintaining, and even increasing, the economic value of these property rights, combined with an interest in learning and information, leads to a flowering of ecological engineering approaches for managing ecosystem services. Investment in green technology is accompanied by a significant focus on economic development and education, improving people's lives and helping them understand how ecosystems make their livelihoods possible. A variety of problems in global agriculture are addressed by focusing on the multifunctional aspects of agriculture and a global reduction of agricultural subsidies and trade barriers. Recognition of the role of agricultural diversification encourages farms to produce a variety of ecological services rather than simply maximizing food production. The combination of these movements stimulates the growth of new markets for ecosystem services, such as tradable nutrient runoff permits, and the development of technology for increasingly sophisticated ecosystem management. Gradually, environmental entrepreneurship expands as new property rights and technologies co-evolve to stimulate the growth of companies and cooperatives providing reliable ecosystem services to cities, towns, and individual property owners. Innovative capacity expands quickly in developing nations. The reliable provision of ecosystem services as a component of economic growth, together with enhanced uptake of technology due to rising income levels, lifts many of the world's poor into a global middle class. Elements of human well-being associated with social relations decline in this scenario due to great loss of local culture, customs, and traditional knowledge and the weakening of civil society institutions as an increasing share of interactions take place over the Internet. While the provision of basic ecosystem services improves the well-being of the world's poor, the reliability of the services, especially in urban areas, become more critical and is increasingly difficult to ensure. Not every problem has succumbed to technological innovation. Reliance on technological solutions sometimes creates new problems and vulnerabilities. In some cases, societies seem to be barely ahead of the next threat to ecosystem services. In such cases new problems often seem to emerge from the last solution, and the costs of managing the environment are continually rising. Environmental breakdowns that affect large numbers of people become more common. Sometimes new problems seem to emerge faster than solutions. The challenge for the future is to learn how to organize socioecological systems so that ecosystem services are maintained without taxing society's ability to implement solutions to novel, emergent problems.

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Chapter 11

Communities, Ecosystems, and Livelihoods

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Main Messages ***262***

11.1 Introduction **262**
11.1.1 Rationale for Conducting Community-based Assessments
11.1.2 Theoretical Background

11.2 Methods **265**
11.2.1 Diversity within and among Assessments
11.2.2 Approaches and Methods
11.2.3 Contribution of the MA Framework to Community Assessments

11.3 Findings: Community Assessment Contributions **270**
11.3.1 Ecosystem Services and Local Livelihoods
11.3.2 Local Management of Ecosystems
11.3.3 Cross-scale Interactions and Social Networks

11.4 Implications for Policy-making **275**

11.5 Conclusions **276**

REFERENCES **276**

BOXES

11.1 Two Methods of Community Engagement: Vilcanota and San Pedro de Atacama

FIGURES

11.1 San Pedro de Atacama, Chile
11.2 Participatory Mapping Exercise at Macubeni Village, Eastern Cape, South Africa
11.3 Local People Working in the Agricultural Terraces of Sistelo, Portugal

TABLES

11.1 A Typology of Community Participation and Knowledge Control: Selected Examples

Main Messages

Community-based assessments are necessary components of multiscale assessments such as the MA. They capture real-life experiences of changes in ecosystems and human well-being. They also give information about existing management systems behind ecosystem services. In addition, a fine-grained look highlights processes and patterns that would not otherwise be evident, such as key resources situated in fine-scaled patches and appropriate times for management interventions. Understanding the co-evolution of knowledge, ecosystems, social institutions, and management practices; their complexity, unevenness in space and time (lumpiness) and nonlinearity; and the feedbacks among them is at least as important as documenting causes and effects.

Local communities are not mere spectators, but active managers of ecosystems' capacities to deliver services. Community management systems are continuously evolving; some disappear while others are revived or created from scratch. Many communities possess local knowledge about the interactions between humans and ecosystems, and affect ecosystem services and human well-being positively. For example, in Xinjiang, Western China, local people have elaborate traditional underground water harvesting structures that maintain both water quality and quantity. However, community-based management in itself does not guarantee proper ecosystem management. In the Eastern Himalayas, for example, national economic incentives have led some communities to cut down indigenous forests. Institutional frameworks that support stewardship of ecosystem services are required. Recognition of the role of communities as stewards of ecosystem services, and their empowerment, is essential to strengthen the capacity to manage ecosystems sustainably for human well-being.

Diversity in ecosystems is important in reducing communities' vulnerability. Most communities seek to maintain a diverse range of livelihood options. This diversity buffers people against shocks and surprises such as climatic and economic fluctuations. In Papua New Guinea and Indian villages, for example, local farmers cultivate a wide variety of crops to avert the risk of crop failure. In Bajo Chirripó, Costa Rica, local communities nurture a mosaic landscape, consisting of sacred places, springs, agroecosystems, and high mountains, thereby creating a diversity of livelihood options at the local level.

Spiritual and cultural values of ecosystems are as important as other services for many local communities. Ecosystems provide a sense of place and identity for local people, in addition to other ecosystem services. These intangible values, including aesthetic and recreational values, provide a rationale for management, and precipitate management practices that enhance ecosystem resilience through caretaking and custodianship. In Vilcanota, Peru, spiritual values and belief systems, including the belief in Pachamama (Mother Earth) that encompasses the view that Earth is a living being, have allowed for the maintenance of a cultural identity among the Quechua peoples of the southern Peruvian Andes. In Kristianstad Wetlands, Sweden, local farmers have again begun to cultivate land previously abandoned, not for economic gain, but for the sense of place and identity that comes with the cultivation of this land. However, in many places, these values and belief systems have been eroded, leading to a shift in community-based management practices. For example, in San Pedro de Atacama, Chile, the erosion of the collective indigenous identity due to economic development has led to the sale of land to outsiders, and a consequent decline in agriculture and related traditional practices.

Communities are affected by larger-scale processes, but their ability to cope with and shape change varies. For example, decisions taken at higher scales often do not take into account the realities of local communities, resulting in negative impacts at the local level. Communities that cope with these external forces have learned to adapt or even take advantage of them by creating horizontal links with other groups, forming alliances with powerful actors at higher spatial scales, and linking with national or global processes such as policy forums, markets, and multinational agreements. When conditions become impossible to adapt to, for example due to inflexible national policies, people are forced to migrate or face a reduced quality of life. In Sistelo, Portugal, for example, a government afforestation program in common property land diminished the locally available livelihood and coping strategies, accelerating the process of rural–urban migration.

Vertical and horizontal collaboration that includes communities can improve ecosystem management and human well-being. Key actors, social networks, trust-building processes, and bridging organizations across scales are important vehicles in this process. In Kristianstad Wetlands, Sweden, for example, local managers are using an international program to strengthen development through the conservation of valuable local wetlands. In Papua New Guinea, trade links between islands ensure ecosystem diversity and enable people to cope with change.

Capturing the complex and dynamic nature of the interactions between ecosystems and humans requires complementary conceptual frameworks. Several community-based assessments adapted the MA framework to take account of more dynamic interplays between variables, capture fine-grained patterns and processes in complex systems, and allow for the integration of worldviews that regard nature as animate entities. In Vilcanota, Peru, and Bajo Chirripó, Costa Rica, for example, other conceptual frameworks were used that incorporated both the MA principles and local cosmologies. In southern Africa, various frameworks were used in parallel to offset the MA framework's shortcomings as a community assessment tool.

11.1 Introduction

The MA community assessments were conducted across five continents in many different settings. The contexts ranged from remote, highly traditional people using ecosystems on a day to day basis, to recently democratized but poor semi-urban people who are forced to rely on ecosystems as safety nets during times of extreme poverty, to urbanized professionals who care about ecosystems and who want to manage them better for biological and cultural values. Apart from being in different countries and on different continents, the community assessments that formed part of the MA varied widely in terms of the livelihoods of the communities involved, the nature of the people's relationship with their natural resources, the cultural characteristics of the community, and the biomes or ecosystems where people were situated.

This chapter is mainly based on examples and emerging insights on the role of local communities in ecosystem management generated by the community-based assessments of the MA, and other MA sub-global assessments that included community perspectives (San Pedro de Atacama, Coastal BC, Bajo Chirripó, Tropical Forest Margins, India Local, PNG, Vilcanota, Laguna Lake Basin, Portugal, São Paulo, SAfMA Livelihoods, Sweden KW, Sweden SU, Northern Range, Downstream Mekong, Western China, Eastern Himalayas, Sinai, and Fiji). The chapter also draws on published studies and theoretical principles. It emphasizes the people-within-ecosystems perspective and the social dimensions of managing dynamic ecosystems at local to regional

scales. It focuses on local communities' influence on the capacity of ecosystems to generate services, and the role of these services in their livelihoods. It also explores the significance of empowering and enhancing the capacity of local communities as custodians of ecosystem services (for example, Johannes 1981; Nabhan 1997).

Community empowerment may help improve livelihood options and the ability to redirect and use external drivers for enhancing community well-being. The empowerment of local communities is increasingly important in a global society where people in one part of the world are dependent on ecosystem services in another part. This requires engaged communities with institutions that provide incentives to respond to and shape change for social–ecological sustainability. It also requires governance systems that allow for and support community processes that improve the capacity of ecosystems to generate services.

By focusing on the peoples' perspectives and their management systems, it becomes possible to address:

- how local users view ecosystem services and incorporate traditional knowledge and practices;
- how the community views indicators of human well-being;
- how local people manage ecosystem capacity behind those services, including management practices, institutions, and governance systems;
- how local people are affected by large-scale processes, and how they shape or cope with the resulting changes; and
- the linkages between communities, institutions (norms and rules), and organizations at other scales, and the role of social networks in the vulnerability or resilience of local people.

Hence, the overall perspective of the chapter is that local communities are not just recipients of ecosystem services, but influence and shape the capacity of ecosystems to generate services. Despite claims of integrative analyses, social systems and ecosystems are often dealt with separately. Here, we attempt to understand the feedbacks between community-level human adaptations and ecosystem change, and are interested in how communities cope with changes precipitated by processes or events operating at different temporal and spatial scales. The chapter highlights the *processes* that characterize human–ecosystem interactions, also called social-ecological systems (Berkes and Folke 1998; Gunderson and Holling 2002).

This section examines the rationale for community-based assessments, including a discussion of the underlying theory. The next section introduces the community-based assessments and highlights the diversity of approaches and methods employed, including alternative conceptual frameworks for assessments of social-ecological systems. The section after that discusses the major findings and insights of the community-based assessments, focusing on ecosystem services and local livelihoods, local management systems, and cross-scale interactions. The overall implications of these findings for ecosystem management are offered in the next section. The examples cited in this chapter are contributions from representatives of the community assessments, who are also authors of this chapter, unless otherwise stated.

11.1.1 Rationale for Conducting Community-based Assessments

Local people shape ecosystems, and ecosystem services should not be assessed without recognizing this. Furthermore, communities are the primary users and managers of most ecosystems, and are aware of their needs and goals in ecosystem management. Including public participation in scientific assessments adds local and indigenous perspectives to scientific knowledge (Functowicz and Ravetz 1990). Assessments with local participation are able to incorporate a more pluralistic perspective, increase public confidence in scientific findings, and ensure representativeness in scientific processes (Bäckstrand 2004). In addition, assessments where traditional societies are involved have the potential to ensure continuous use and transmission of traditional knowledge and practices. The importance of public participation in scientific processes is increasingly being recognized, and the MA community-based process is a step in that direction.

The challenge of improving ecosystem management is to develop institutional structures that are similar in scale to the ecological and social processes they are meant to manage. Such institutions should also, however, establish links with processes and institutions operating at other spatial and temporal scales. Community-based assessments generate information on slow-moving, long-term changes and on more rapid short-term change. They also help identify workable management interventions, by incorporating the knowledge and experience of primary resource users.

Community-based assessments represent an appropriate way to obtain fine-grained information about ecosystem services and processes and their relationship with human well-being for a number of reasons:

- *The community is the most direct link to the ecosystem.* Local people are acutely aware of ecosystem services in their area, which is why the local assessments found many examples where communities were able to identify threatened and valuable resources that distant researchers working at coarser spatial scales were unaware of. In India, for example, local people have been the custodians of local medicinal plants and natural health remedies for generations (India Local). These medicines and health remedies are now being re-discovered by health food producers and pharmaceutical companies. Local people, being closest to the affected area, have the potential to detect and respond to ecosystem change long before remote scientists can. Ecosystems are part of the cosmology of many communities, in particular of traditional societies, and much of their folklore, belief systems, and management practices have co-evolved with ecosystems.
- *Local resource users and managers possess traditional and local ecological knowledge that provide lessons for sustainable development.* (See also Chapter 5.) Local ecological knowledge consists of externally and internally generated knowl-

edge about resource and ecosystem dynamics, generally a combination of scientific knowledge and practical experience. (See Glossary for definitions, and Chapter 5 for broader discussion.) All the community assessments found that traditional and local knowledge play important social functions. Communities also use this knowledge in forecasting ecological events, managing and regulating resource use, adapting to change, and using and combining technology. For example, indigenous farmers in the high Andes of Bolivia and Peru look to the stars toward the end of every June to forecast weather for the next six months. If the eleven-star constellation known as the Pleiades appears bright and clear, they anticipate early, abundant rains and a good potato crop. If the stars appear dim, however, they expect a smaller harvest and delay planting in order to reduce the adverse impact of late and scarce rainfall (Orlove et al. 2000). However, in many communities, traditional knowledge has all but disappeared, existing mostly in the elderly, with young people turning their backs on it. In San Pedro de Atacama, Chile, this erosion of traditional knowledge has been identified as a problem, and some communities are trying to revive it. In areas where traditional knowledge has been preserved, it can contribute to local development, either in its original or in modified form. Pardhi hunters in India, for example, are now using their traditional metal work skills, originally developed to make weapons and hunting traps, to produce commercial cutlery (India Local).

- *Local resource users may detect and respond to early signs of fluctuations in the flow of ecosystem goods and services.* In the Philippines, local fisherfolk detected changes in the fish populations of Laguna Lake in the 1970s, spearheading conservation and mitigation efforts supported by government. In Egypt's Sinai Desert (Sinai) and in Richtersveld National Park, South Africa (SAfMA Livelihoods), nomadic and semi-nomadic pastoralists know when to move with their livestock in advance of dry spells. Communities in the Great Fish River area of the Eastern Cape start preparing for rainfall events before they happen by cleaning water-harvesting structures (SAfMA Livelihoods). People of Hudson Bay, Canada, have knowledge about changes in variables related to climate and link this knowledge to the long history of close interaction with nature (Riedlinger and Berkes 2001). Olsson and Folke (2001) describe how members of a local fishing association in Sweden use indicators at various scales that are critical in detecting fundamental changes in ecosystem dynamics; management decisions are guided by monitoring these indicators to keep track of environmental change. In Peru, farmers have been forecasting El Niño events for at least 400 years by looking to the stars, a capability modern science achieved less than 20 years ago (Orlove et al. 2000). In India's Western Ghats, local villagers noted that potentially valuable rice varieties were on the verge of extinction and started taking special measures to conserve them; if appropriate procedures are followed, these traditional varieties could lead to local economic benefits (India Local).
- *Local knowledge can complement scientific knowledge.* (See also Chapter 5.) The entire MA process has demonstrated how local and scientific knowledge can be combined to improve our understanding of ecosystem services and functioning. In the process, lessons are learned on all sides. A good example is the People's Biodiversity Register in India, where villagers and schoolteachers contribute to biodiversity inventories throughout the country (India Local). The information is incorporated in the Indian National Biodiversity Strategy and Action Plan within the mandate of the National Biological Diversity Act, 2002. Other examples include villagers in Karnataka who brought the decline in endemic fish populations to the attention of biologists (India Local), and local experts in South Africa's Great Fish River valley who helped ecologists improve their understanding of landscape dynamics (SAfMA Livelihoods). The MA process has provided further documentation over a wide range of human and ecological systems of how local knowledge can be combined productively with formal knowledge, including an overview of the many pitfalls associated with this work. (See Chapter 5.) Combining knowledge based on different worldviews is not easy, and there are major ethical and methodological problems that need to be overcome (Cundill et al. 2004).

11.1.2 Theoretical Background

Social-ecological systems are complex, self-organizing systems dominated by nonlinear phenomena, discontinuity, and uncertainty (Costanza et al. 1993; Levin 1999). This means that it is hard to make a distinction between ''drivers'' of ecosystem change (see Chapter 7) and ''responses'' at the local level, since the manager's response is a driver at the scale of the ecosystem being assessed. In this sense, the MA concept of endogenous and exogenous drivers became particularly important in community level assessments. However, the distinction and classification of endogenous versus exogenous drivers can lead to much ambiguity and circularity of argument, and therefore we have chosen not to use these terms, but rather to discuss interactions in social-ecological systems.

Sustainability is a process rather than an end product. The lesson from complex systems thinking is that management processes need to be flexible and adaptive in order to deal with uncertainty and surprise (Gunderson and Holling 2002; Dietz et al. 2003). All sub-global assessments found that governance was a critical component of management, and that weak systems of governance were invariably associated with social-ecological systems that struggled to adapt to change. Sustainable governance therefore requires the active involvement of people and communities that build knowledge and understanding of resource and ecosystem dynamics, develop management systems that interpret and respond to ecosystem feedback, and support flexible organizations, institutions, and adaptive management processes (Berkes et al. 2003). The governance system needs to be adaptive to external influences and change. The challenge

is not to avoid change, but to sustain a desirable social-ecological state in the face of complexity, uncertainty, and surprise (van der Leeuw 2000). Some insights about how to do this can be derived from communities, who have historically adapted their resource management systems and institutions to cope with change and uncertainty in nature (Feeney et al. 1990; Scoones 1999; Pretty and Ward 200; Fabricius and Koch 2004).

Resilience—the capacity to cope with, reorganize, and develop following change—is an important element of how societies adapt to external forces such as global environmental change (Holling 1973; Holling 1986; Folke et al. 2002). Resilience is an important element in efforts aimed at strengthening the capacity to manage ecosystems for human well-being (Carpenter et al. 2001; Gunderson and Holling 2002). (See MA *Current State and Trends,* Chapter 6.) There are many examples of communities whose resilience has been eroded (for example, Ainslie 2003), but there are also examples of those that have enhanced their resilience (for example, Kristianstad Wetlands, Sweden). Such community-based management systems have developed knowledge and practice for how to live with change and uncertainty (Berkes 2004).

The focus in this chapter starts at the level of the community, defined as a social group possessing shared beliefs and values, stable membership, and the expectation of continued interaction. It can be bounded geographically, by political or resource boundaries, or socially as a community of individuals with common interests (Berkes et al. 2001). Furthermore, a community is not a static, isolated group of people. Local responses are influenced by global and national trends and fads, which can lead to changes in incentive structures and the modification, or even erosion, of self-organized community-based systems.

The MA community assessments focused on communities directly involved in resource and ecosystem management, and were conducted in both temperate and tropical regions, including various biomes, from mountains to coastal areas. The sizes and scales of these areas varied, but they were all local in scale relative to national or regional sub-global assessments. The Bedouin in the Sinai desert in Egypt and semi-nomadic pastoralists in Richtersveld National Park, South Africa (SAfMA Livelihoods), for example, manage and use vast areas, but focus their management on key resource areas. In more resource-rich areas such as Sweden KW and India Local, where human density is high, the community-based management units are much smaller, and the assessments not only assessed the use of ecosystem services, but also their management and governance.

In the context of the MA, ''community assessments'' must at least meet the following criteria:

- there is some level of local participation in aspects of data collection and assessment design;
- data are collected at a fine resolution, typically at spatial scales of between 1:10,000 and 1:50,000, and interpreted in the context of local, national, and global factors;
- qualitative, quantitative, formal, and informal information are combined;
- local knowledge is incorporated into the assessment findings and recommendations; and
- the results are useful to *local* decision-makers, for example, those in community organizations, villages, or municipalities.

11.2 Methods

11.2.1 Diversity within and among Assessments

When dealing with communities, researchers and practitioners face a number of pitfalls. One is striving for, or assuming, homogeneity and glossing over differences in needs, cultures, and customs simply because people live in the same area. The other is assuming that only groups that are geographically close together share the same interests. This heterogeneity is illustrated by the communities involved in the MA. Within each community, different groups have different interests, livelihood strategies, demographics, networks, and interactions with ecosystems. Among rural groups living in the Gariep Basin in South Africa, for example, there is considerable variation in people's interactions with and connectedness to ecosystems. For many households, wage labor, remittances, and migration have replaced agriculture as the main sources of income, but most people still maintain a link to ecosystems by owning some livestock, cultivating crops, and harvesting fuelwood for heating and cooking (SAfMA Livelihoods).

Several ''livelihood clusters'' (functional units of people who make their living in similar ways) occur at the village level. These clusters overlap in terms of their geographical distribution, kinship linkages, and institutional affiliations. Individuals can belong to more than one livelihood cluster and the differentiation is more complex than gender or age groupings. In Mala, India, up to 20 castes and more than 25–30 user groups, all with different needs and value systems, comprise a village. Hence, knowledge of changes in medicinal plants is mainly held by medicinal plant collectors, while farmers best understand land use change (India Local).

Gender roles are also an important component of community diversity. In Bedouin society, for example, women are most familiar with the variety of weeds and herbs used for treating infant diseases, and possess knowledge about agro-diversity practices (Sinai). In the Gariep Basin, knowledge about trends in the availability of fuelwood is held mainly by women, whose role it is to collect fuelwood on a daily basis for household use; women are also responsible for collecting water, and have a special interest in maintaining and protecting small perennial fountains and sacred pools (SAfMA Livelihoods). Among many local groups, for example, the Egyptian Bedouin, Nama pastoralists at Richtersveld, and Xhosa villagers in South Africa's Great Fish River basin, men make decisions about livestock management and have a special interest in managing rangelands.

One implication of diversity for ecosystem management is that local governance structures should recognize the various interest groups and their different roles in ecosystem management. The implication for conducting assessments

is that these different groups should all be involved in the assessment process.

11.2.2 Approaches and Methods

The community-based assessments faced a number of methodological challenges. One was the diversity described above, which required MA methods and frameworks to be adapted to the local context. A related challenge was how to engage communities in a process that had to a large extent been pre-designed, in terms of the conceptual framework, which was used to varying degrees to determine both which questions were considered important and how to interpret assessment findings. A third challenge was securing the continued buy-in of potential assessment users; even assessments that had local involvement prior to initiating the assessment process often found that the buy-in was superficial and waned once users realized that the assessments were not able to live up to local expectations of control and benefits; assessment teams had to both ensure a range of long-term and short-term benefits to local users and develop mutual respect. A fourth challenge was cross-scale interactions, which required a multiscale approach. Finally, the assessments had to rely on several types of data, demanding flexible methods for collecting and validating both scientific and oral information.

The methods are described in each assessment, and so this section does not seek to provide the reader with a road map for how to conduct an integrated community-level assessment. Rather, the intention is to highlight the necessity of adapting the assessment process to the local context, and to provide examples from various assessments around the world that illustrate how this can be achieved.

11.2.2.1 Community Engagement and Benefits

The MA community-based assessments emphasized community participation in the assessment process; they were performed in collaboration with local people who are involved in resource and ecosystem management for livelihoods or for other values. (See Box 11.1) Consequently, it would not be appropriate to assess biological resources and ecosystem services of a certain area and afterwards gather stakeholders to become involved in their management. The design of the MA allowed considerable flexibility, and therefore the social dimension of the assessment areas could be assessed through an inventory of the different actors involved in resource and ecosystem management. This has been referred to as a social inventory; examples include Sweden KW, SAfMA, and San Pedro de Atacama.

From the outset, it was essential to plan for long-term benefits to communities that were involved in the assessments. These benefits needed to outlast the short-term involvement of MA practitioners. Potential long-term benefits included: improved ecosystem production and resilience; capacity-building; access to government officials (for example in workshops) to demonstrate local knowledge and desire to initiate projects; availability of all assessment reports to nominated local leaders and to government officials as an information base for future development projects; empowerment of weaker sectors in the community; and the involvement of local schools in capacity development initiatives.

11.2.2.2 Cross-scale Interactions

The community-level assessments were aimed at understanding local level processes. It was therefore necessary for the assessment teams to work across spatial and temporal scales. Local, sub-national, national, and international drivers of change invariably related to political, economic, and biophysical processes at coarser scales, thus forcing the community-level assessments to seek innovative methods of incorporating information from coarser scales into their local level assessments.

In some instances, communities were not aware of the nature and extent of coarse-scale drivers and how these affected their lives, and therefore coarser scale information had to be incorporated by the investigators themselves. But in SAfMA Livelihoods, interactive scenarios (van der Heijden 1996; Peterson et al. 2003) were found to be useful mechanisms to involve communities in identifying and understanding the importance of coarse-scale information linkages. These scenarios were based on an interpretation of information already gathered at the local level by both researchers and local community members, and included national level data on political and economic changes. The scenarios were presented using forum or community theater and digitally enhanced posters summarizing key changes in the relationship between local communities and ecosystems. (See Chapter 10.)

11.2.2.3 Data Collection and Validation

Not all methods of data collection and validation were appropriate in all contexts. One important variable was the level of formal education of the participating community, in other words their literacy and numeracy rates. A second variable was their previous exposure to ecosystem assessments. A third variable was available budget and time. A fourth was the level of direct dependence of communities on ecosystems, and how closely they were involved in ecosystem management, and, correlated with this, their depth of traditional knowledge. To adapt the assessment process to their particular contexts, most community assessments opportunistically combined different methods of data collection.

The methods ranged from low-technology, qualitative interviews (Sinai) to high-technology computerized mapping and Geographic Information Systems (SAfMA and San Pedro de Atacama). Participatory learning approaches were employed to ensure consensus-based interaction with local knowledge. However, this local knowledge alone was not sufficient to gain an understanding of the broad set of processes that affect local social-ecological systems, and therefore had to be combined with a range of formal (historical records, census data, GIS, water and soil quality testing) and informal data (participatory rural appraisal, workshops, in-depth interviews, household interviews). In Vilcanota, Peru, trained local technicians from the communities made observations, did forecasting and back-casting, and dis-

BOX 11.1

Two Methods of Community Engagement: Vilcanota and San Pedro de Atacama

Vilcanota was a community-led assessment with emphasis on indigenous peoples' rights. Methods combined traditional Quechua ecosystem assessment techniques with contemporary participatory enquiry methods that promote equity and social justice through the direct involvement of, and control of the process by, the local indigenous population. Quechua methods included the use of prophecies and myths (where ecosystem processes and practices are communicated through myths); forecasting and backcasting techniques; and memory, writing, record keeping, and coding information traditions (such as the *Khipu* system, a binary coding and knowledge registration system). Contemporary participatory enquiry methods included community-based evaluation, deliberative democratic evaluation, practical participatory evaluation, and empowerment evaluation.

Within this framework, emphasis was given to (1) the goals and interests of the Vilconata communities and (2) equity issues and dimensions of the process. The goals and interests included:

- the problem-solving orientation of the assessment (the assessment was being used to establish a spiritual park in the Vilcanota area);
- the achievement of political goals such as social justice and a voice in decision-making; and
- the incorporation of the Quechua worldview, particularly the importance of cultural and spiritual values.

The equity and process issues included:

- local control of decision-making;
- local control over the selection of participants; and
- significant participation by various members of the community.

The assessment process helped Vilcanota communities gain control over the information produced. By interpreting ecosystem phenomena with a conceptual framework based on their worldview, the communities managed such information and applied it to the establishment of the spiritual park in a manner that responded to their traditional institutions, customary laws, and economic, social, and cultural aspirations.

The ***San Pedro de Atacama*** assessment was a multistakeholder process with an emphasis on engaging all affected parties. The area's social complexity (legitimate demands from the indigenous communities, high concentration of government development initiatives, large-scale mining, an emergent tourism industry, globally relevant astronomical projects and ongoing conflicts between users over water and access to economic opportunities presented considerable challenges. The advisory committee was set up to address these issues and generate dialogue and trust between users and the assessment team. The assessment team proposed the creation of the advisory committee as a forum to:

- share information, knowledge, and experience;
- get to know and integrate diverse perspectives;
- provide a forum for communication among the actors; and
- go beyond institutional limits to express and discuss topics and perspectives in a broad and unconstrained manner.

Seven meetings were held during the process, in which the team and the group went over the assessment steps based on the best information available: conditions and trends (baselines discussions), drivers (plenary dialogue), scenarios and responses (group workshops). Complementary presentations were presented by the same representatives and their organizations and by researchers from other sub-global assessments visiting the area.

This advisory committee became the only forum in which diverse actors could sit together to discuss important development issues from their very different perspectives and interests. Hence, a follow-up of this group was proposed by the users.

cussed the community understanding of ecosystem functioning during village meetings. In India Local, school students spent time with knowledgeable individuals to document their knowledge. Local people also formed study groups by volunteering to address various topics based on their expertise and preferences. During this process they documented their knowledge of birds, grasses, etc. Field visits and long duration stays of external researchers facilitated and added to these efforts.

Difficulty in comparing findings arose from both the conceptual models used (discussed later in this chapter) and the methods employed to communicate among different knowledge systems. All assessments acknowledged uncertainty in findings, and took it to constitute an inherent property both of complex systems and of knowledge systems that cannot be tested using modern scientific methods of validation. Most assessments dealt with this uncertainty through various triangulation methods aimed at validating both scientific and local knowledge. (See also Chapter 5.) However, the techniques used varied significantly among assessments. All the local assessments gave feedback to local communities. The feedback methods used included holding workshops, presentations, or theater (SAfMA Livelihoods), involving communities in carrying out the assessment (Bajo Chirripó), compiling reports and outputs of the assessments (Vilcanota), participatory validation (Portugal, Sweden KW), developing educational modules in the form of videos and booklets (Bajo Chirripó, SAfMA Livelihoods, and San Pedro de Atacama), conducting workshops with advisory committees and users (Sweden KW and Sweden SU), translating reports into local languages and in terms of local people's worldviews (India Local, Vilcanota, and Bajo Chirripó). Some assessments (San Pedro de Atacama, Vilcanota, and India Local) developed ethical and rights-based agreements (such as those that the International Society for Ethnobiology used in Peru) for the use and dissemination of information, recognizing that researchers have specific responsibilities in that regard and that some forms of knowledge are sacred. Many communities saw the documentation of their knowledge as the departure point for facilitating dialogue with other stakeholders. It was, however, necessary for this knowledge to be validated by other local experts and scientists.

While all community assessments, by definition, involved local people, the level of community participation, and community control over the assessment process and the

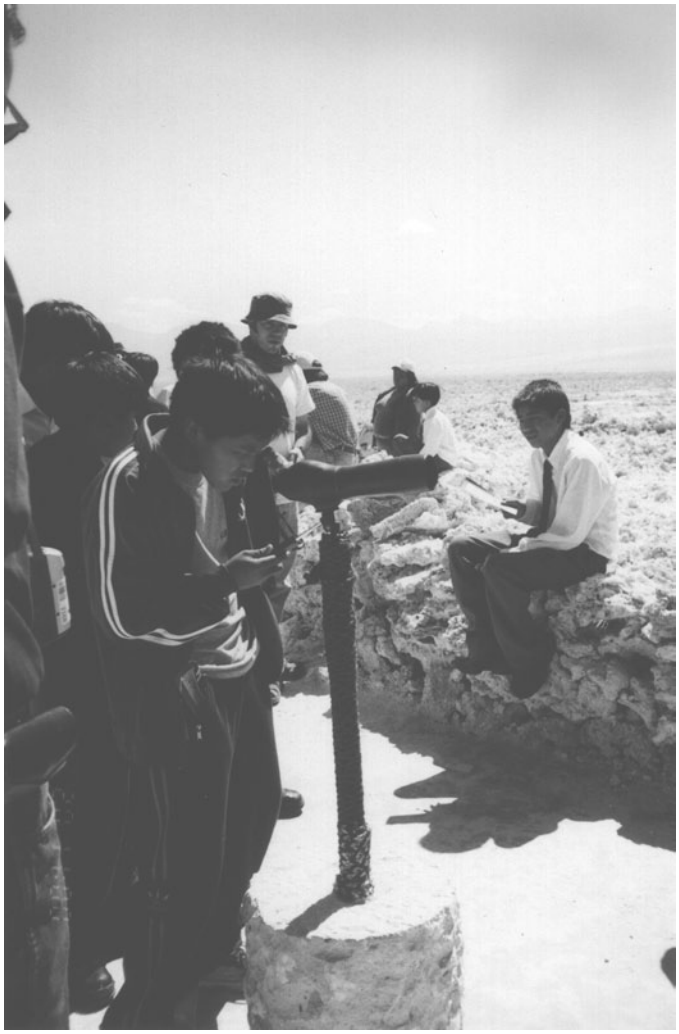

Figure 11.1. San Pedro de Atacama, Chile. Children from local schools visit Laguna Chaxa, most of them for the first time, as part of the educational activities coordinated within the assessment. Chaxa is part of the Flamingo National Park—one of the main tourist attractions in the area. (Photo by Andrés Marín R.)

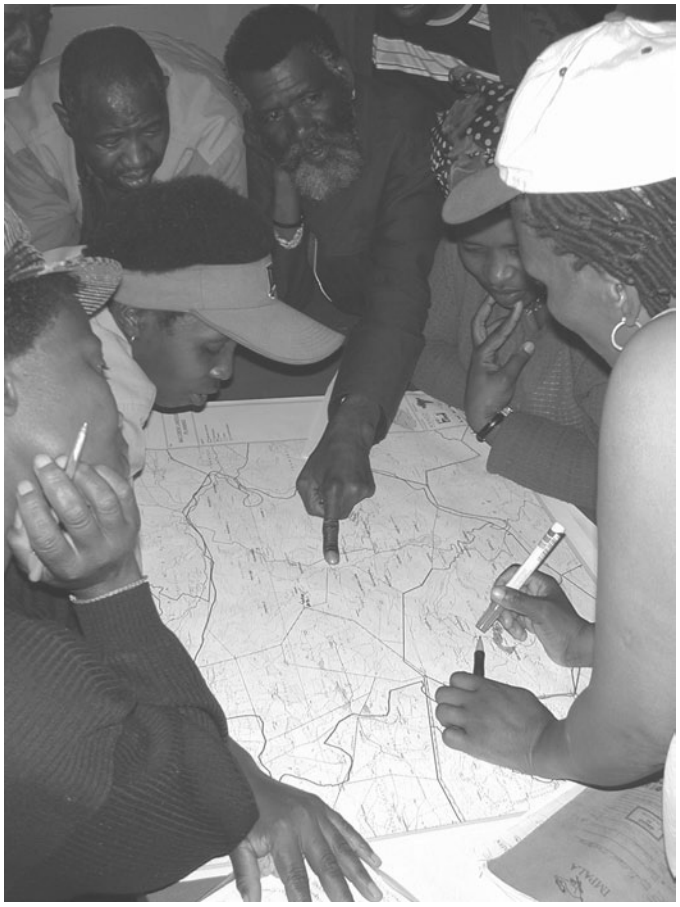

Figure 11.2. Participatory Mapping Exercise at Macubeni Village, Eastern Cape, South Africa (SAfMA Livelihoods). Mapping exercises such as this enable illiterate people to contribute local knowledge about landscape and land use change and changes in political boundaries. Such exercises also make assessments more accessible to people who would normally find them quite daunting. (Photo by Christo Fabricius)

use of their knowledge, varied widely among assessments. Table 11.1 is a typology of the community assessments' knowledge sharing developed as background for this chapter; the indicators used in developing the table include the communities' ability to present assessment results to stakeholders, the use of assessment information by communities in other documentation, and representativeness and level of attendance at workshops. The table shows three broad categories of knowledge sharing: (1) *community-led,* where both community participation and community control of knowledge and the assessment process was strong (Vilcanota and Bajo Chirripó); (2*) collaborative,* where community participation was strong but community control of knowledge and the assessment process was moderate (SAfMA Livelihoods, Sweden KW, and India Local); and 3) *information sharing,* where community participation was moderate, and community control of the assessment process and knowledge was moderate to weak (San Pedro de Atacama, Portugal, and Coastal BC).

11.2.3 Contribution of the MA Framework to Community Assessments

All assessments made use of the MA conceptual framework as a conceptual guide. The framework proved useful in conceptualizing the relationship between people and the natural environment through its appreciation of multiple scales of analysis, and cross-scale linkages. However, as the MA authors recognized from the outset, the framework's apparent linearity did not fully capture the complex interactions among the various different framework elements (MA 2003, p. 26).

11.2.3.1 Opportunities and Challenges Presented by the MA Framework

The MA formalized and gave recognition to the principles of cross-scale interaction in social-ecological systems, as well as the significance of different knowledge systems. This came in response to criticisms that big decisions too often fail to consider local community interests when their feasibility is appraised, and that many interventions, designed

Table 11.1. A Typology of Community Participation and Knowledge Control: Selected Examples

Type of Participation	Assessment	Definition of Research Questions	Conceptual Framework Used	Validation	Feedback	Who Participated
Community-led	Bajo Chirripó	jointly defined by community members and researchers	MA with modifications based on local visions	local people conducted and validated the assessment with scientists	internal feedback, by communities themselves	various groups in the community and facilitators
	Vilcanota	defined by communities	own conceptual framework developed in response to MA	local people conducted the assessments with assistance of specialist facilitators	on-going internal feedback, by community members	various groups in the community and facilitators
Collaborative	India Local	defined jointly, according to local priorities	MA and others	local people provided, validated, and cross-checked most information	on-going feedback and refinement	various village-level stakeholders and scientists, through interviews and interaction
	SAfMA Livelihoods	defined by researchers	MA and others	local people provided and validated most information	on-going feedback, by community in regular community meetings	villagers, facilitators, and scientists, mainly through participatory methods
Information sharing	Coastal BC	community contributed to the formulation of research questions	MA only	investigators validated the data	community received feedback at the end of the process	community representatives participated in the planning phases
	San Pedro de Atacama	defined by scientists, with inputs from community leaders	MA only	findings validated by stakeholders at the end of the assessment	community received feedback at the end of the process	community was one of the participants
	Portugal (Sistelo)	defined by researchers, with some inputs from the community	MA only	local people were asked to comment	local people were presented with information and asked to comment	mainly community members or villagers and some local and regional organizations
	Sweden KW	defined by researchers	MA and others	findings validated by stakeholders continuously during the assessment	continuous	a range of stakeholders were interviewed and consulted

with the local scale in mind, fail to have any impact because they are overshadowed by more powerful coarse-scale drivers. The MA framework therefore directed investigators and communities toward looking at coarse-scale drivers such as sub-national, national, and global policies or economic change, and their effects on fine-grained ecological and social processes. The emphasis on spatial and temporal scale in the MA highlighted the importance of historical and contemporary processes in the design of the community assessments. It also spurred investigators to specifically assess how ecosystem services connect across scales and societal responses operating at local, sub-national, national, and global levels. (See Chapters 4 and 9.) The MA approach in some instances also prompted participants to develop locally relevant scenarios at the local level (for example, SAfMA Livelihoods and San Pedro de Atacama). Locally relevant scenarios were easily understood by primary resource users and managers, and facilitated dialogue between communities and other users with different levels of power. This encouraged all users to confront several possible futures (some of them otherwise inconceivable) in a way that other approaches would not have achieved. Scenarios were excellent tools to evaluate and compare the vulnerability and resilience of management strategies. (See Chapter 10.) Resilient management strategies promote the sustainable use of ecosystem services under many different scenarios, while vulnerable strategies promote sustainable use under few scenarios.

Two major issues concerning the MA conceptual framework arose during the community-based assessments. The first involves the weakness of the framework in portraying the adaptive and dynamic nature of local processes. The framework did well to consider local resource managers (referred to as decision-makers) as part of the system in question, something that has been lacking in traditional approaches to natural resource management. However, the framework did not do justice to the dynamism and interdependence of human and natural systems at the community level. In particular, the MA framework does not allow for consideration of the process of institutional learning, adaptation, and resilience within these systems. Furthermore, communities, since they are ''inside'' the social-ecological system being considered, act both as a *driver* through their management practices and local institutions that shape ecosystem dynamics and as *respondents* to external factors such as technological and policy change. (See MA *Policy Responses,* Chapter 14.)

Second, the conceptual framework represents a particular view of the world, albeit from a combination of various disciplines. Some of the framework's concepts were very difficult to understand in local contexts where different worldviews and epistemologies held sway. Local level assessments therefore married the MA framework with other conceptual models that would help communities and researchers to identify and understand local processes. While some, such as SAfMA Livelihoods and Sweden KW, complemented the MA framework with models that emphasized adaptability and response to environmental feedback, others, such as Vilcanota and Bajo Chirripó, supplemented the framework with indigenous cosmologies to guide their assessments. (See Chapter 5.)

11.2.3.2 The MA Framework ''On the Ground''

The SAfMA Livelihoods assessment team found that local people constantly adjust their livelihood strategies to cope with long and short-term changes in the environment, and that key resources such as water, fuelwood, food, and livestock varied in response to both rainfall and trends in demand. This led to a dynamic interplay between ecosystems and humans, which required that additional conceptual frameworks be used alongside the MA framework. The adaptive renewal model (Gunderson and Holling 2002) enabled the team to conceptualize ecosystems and humans as complex adaptive systems that undergo cycles of collapse and reorganization. The sustainable livelihoods framework (Carney et al. 1999) was useful to conceptualize livelihood strategies as long-term responses to reducing people's vulnerability rather than as short-term coping strategies. The three frameworks were used in a complementary manner, and their combined application helped overcome many of the MA conceptual framework's shortcomings. In the Swedish assessments (Kristianstad Wetlands and Stockholm Urban), the MA framework was enriched by emerging theories of linked social–ecological systems.

Vilcanota took a different approach. Combining the MA framework with complex adaptive hierarchical system theory and, more significantly, a drawing of Incan cosmology created by the Incan chronicler Juan Santa Cruz Pachacuti Yanqui Salccamaygua, the Vilcanota assessment team created an alternative conceptual framework. The pre-Hispanic drawing expresses the specific manner in which Andean peoples perceive, order, and explain their world through time and space and how they understand humans' position and relationship with society, the environment, and the cosmos. The Andean world is believed to be structured into three areas or scales—the *Ukupacha* (the past and the interior world), *Kaypacha* (the world of present and of here), and *Hananpacha* (the future and the supra world) (Milla 1983). The resulting conceptual framework uses these three main hierarchical systems, and expresses space and time as one entity and presents ecological, social, and cultural processes of life as entities. These entities neither exclude each other, nor are they antagonistic, but act as opposites in a complementary manner. The Vilcanota conceptual framework therefore used the cultural conception of *Pacha,* sociocultural processes, and Andean principles such as *Pachakuti* and *Ayni,* which depict cycles of change and resilience, to assess the multiscale processes affecting local ecosystems and local cultures. (See Chapter 5 for further discussion of this framework.)

11.3 Findings: Community Assessment Contributions

From the outset, the community assessments envisaged people, their knowledge and belief systems, and ecosystems as part of the same integrated social-ecological system. Thus

the community assessment participants saw ''drivers'' as factors affecting both people and ecosystems. Human management systems (''responses'') and knowledge are part of the system, and responses, drivers, and services are part of a complex melting pot of internal processes—an amalgam rather than a set of separate building blocks. Feedback between the social and ecological components of the system is continuous and ongoing. Understanding the co-evolution of knowledge, ecosystems, social institutions and management practices, their complexity, variability and unevenness in space and time (''lumpiness''), and nonlinearity, and the feedbacks among them is at least as important as documenting causes and effects.

11.3.1 Ecosystem Services and Local Livelihoods

11.3.1.1 The Importance of History

History is important in understanding people–ecosystem interactions (Fairhead and Leach 1996). In different parts of the world, humans and ecosystems have co-evolved, which has led to the development and refinement of local and traditional knowledge and management strategies through constant adaptation and learning. History is also important to understand the nature and evolution of local institutions. People understand their future by looking at the past, and use the past to reflect on a vision for the future. Historical insights highlight the importance of forecasting, and help to identify key drivers based on reflection. Historical management practices have shaped the current structure and functioning of ecosystems. Therefore, conditions and trends in social-ecological systems need to be assessed over longer periods. In many places, local knowledge is often the only source of such information.

In Peru, the past, present, and future are linked to different landscapes in space, and the whole landscape, and ecosystem processes, are interpreted in terms of that cosmology. Historical events are used to interpret contemporary ecological change such as landscape dynamics and climate change, and even today, people believe that they have to plan for the well-being of future generations (Vilcanota). In Bajo Chirripó, Costa Rica, historical events are linked to ancestral territories, which define the spatial extent of their ecosystems; people recognize historical signs to predict looming disasters such as El Niño events. In San Pedro de Atacama, Chile, traditional knowledge depicts a mythical past of landscapes, spirits, and ecological processes dependent upon each other; this forms the basis of people's cosmology, but waves of colonization and conflict have challenged these belief systems and identities. New state-led initiatives, such as the establishment of the Indigenous Development Area and the Programa Origenes, have, however, led to an enhanced sense of identity amongst indigenous groups (San Pedro de Atacama).

11.3.1.2 The Role of Ecosystems in Reducing People's Vulnerability

A common finding in all the community assessments was that local people living in rural areas cherish and promote ecosystem variability and diversity as a risk management strategy. Diversity of species, food sources, and landscapes serve as ''savings banks'' and ''buffers,'' to enable people to cope with change during adverse times. The diversity of land types and crop types used by different communities living in the same region reduces people's vulnerability by providing livelihood options to fall back on, in case crops or landscapes are negatively affected by catastrophes.

The benefits of promoting ecosystem diversity may not be evident on a day-to-day basis, but they become evident during times of crisis, for example when crops fail, technology breaks down, or during droughts or floods. The Papua New Guinea assessment found that people living on different islands plant different crops, and then trade these between islands to enable them to cope with food shortages due to pest outbreaks or adverse weather conditions (KM–Papua New Guinea). The Vilcanota assessment found that people living at different elevations plant different crops and harvest different biomedicines, using a barter system to exchange tubers, grain, medicinal plants, and other services in a complementary manner; this system conserves genetic diversity, promotes food security, and maintains traditional cultures. In India, local people deliberately conserve sacred groves and, like communities in South Africa's Great Fish River valley, protect sacred pools to enhance ecosystem diversity, as these landscapes act as refuges that nurture indigenous species and their propagules. These propagules form the basis of ecosystem renewal after droughts, when rivers dry up but sacred pools remain water-filled, or after fires, when less dense forests are destroyed but sacred groves remain protected (India Local).

At Qongqota in the Eastern Cape, South Africa, communities have always maintained natural fountains and have been concerned about forest conservation. They do this despite having access to piped water and making their main living from small-scale agriculture, remittances, and urban jobs (SAfMA Livelihoods). These fountains are essential for their long-term survival, and people rely on them when water pumps break or when the government fails to repair broken pipes. The fuelwood from forests and woodlands are essential for wood fires to cook food, especially during economic recessions when workers who send remittances home are made redundant, or when the prices of alternative fuels such as paraffin rise due to currency fluctuations or global fossil fuel shortages. In many cases, biomedicines are used in emergencies, or to supplement conventional medicines.

Around the world, wild fruit provides crucial vitamins and minerals at critical times of the year and at critical stages in infants' physical development. Bushmeat and fish supplement poor people's protein intakes and are sold to supplement meager incomes. Key landscapes such as wetlands, high pastures, sacred forests and groves, and sacred pools provide ''stepping stone'' resources, that is, infrequently used resources that enable people or animals to overcome brief periods of severe food, water, or energy shortages. Biodiversity creates employment and income through sales of ecosystem products and creates jobs from tourism and related economic activities. This further reduces people's vulnerability by increasing their livelihood options. Resource-

rich patches act as safety nets for biodiversity. In India, for example, many sacred groves protect the upper reaches of watersheds, serve as refuges for non-harvested beehives, and provide habitat for many other plants and animals (India Local).

However, ecosystem conservation alone does not guarantee reduced vulnerability in communities—there are many vulnerable communities living in well-conserved ecosystems (for example, in Costa Rica's Cabecar Territories and at Richtersveld, South Africa). In Richtersveld, South Africa, although local ecosystems form part of a national conservancy area to which communities have access, regional and local economic constraints make communities very vulnerable. Therefore additional strategies, other than ecosystem conservation, need to be put in place to make people more resilient (SAfMA Livelihoods).

11.3.1.3. Well-being and Poverty from Different Perspectives

The relationship between human well-being and poverty varies both spatially and temporally among and within communities, based on the broader context of local culture, wealth, access to ecosystems, age, and gender. This complexity often causes conflict in decision-making for communities and ecosystems in policy development (for example, India Local).

Well-being should thus be defined and considered differently in different settings. For example, in Bajo Chirripó, people do not distinguish between their own well-being and that of the ecosystem, while in Sistelo, Portugal, subsistence farmers see ecosystem services as extractable resources and have five dimensions of well-being, consistent with the MA framework. In San Pedro de Atacama, different cultural groups with different uses for ecosystems define well-being differently. In Vilcanota, well-being is spiritually defined through people's relationship with mountains and landscapes. In the Kristianstad Wetlands, Sweden, a perceived crisis in ecosystem condition triggered a transformation of local priorities, leading to a shared community vision of the landscape and the importance of its associated cultural values to community well-being and development. Similarly, in South Africa, people emphasize both the material and cultural values of ecosystem services. In certain settings they would define their well-being in terms of material benefits, security, and provisioning services while in other settings they would define their well-being in spiritual terms.

People co-opt modern technologies and beliefs when appropriate, or when it cannot be avoided, and adhere to a mix of modern and traditional principles. In some cases, individuals and groups are opportunistic in using different value systems to suit them. Therefore, while the relationship between human well-being, poverty, and ecosystem services may appear static when viewed from the outside, the interpretation of this relationship is in fact highly dynamic at the local level.

11.3.1.4 Spiritual and Cultural Values

Most terrestrial landscapes have been influenced by historical or contemporary cultural practices, and few are pristine wilderness areas that are frozen in time. (See MA *Policy Responses,* Chapter 14.) While provisioning services such as water, medicinal plants, fuelwood, and food are very important, spiritual and sacred elements in the local landscape also have specific and important value to local people across all the assessments. In several cases, spiritual values coincided with other values, such as biodiversity, water supply, biomedicines, and fuel. The maintenance of these values results in community-based ecosystem management strategies that enhance landscape patchiness and diversity, thereby promoting resilience.

Rituals and traditions are central to the culture and identity of the Xhosa people of South Africa's Eastern Cape (SAfMA Livelihoods). Key resource areas are fundamental to the performance of these rituals and include sacred pools and dense forests. Each of these sites has particular rituals associated with them, with specific benefits. These sites thus provide a place of direct communication with the spirit world where people can access blessing and health and also provide thanks and veneration through the performance of particular rituals. The sites are thus critical points in the landscape where culture in the form of traditions and connection with the ancestors is maintained. In many cases, they also enhance social–ecological resilience. For example, the sacred pools never dry up; the vegetation surrounding them is denser and provides a protective canopy, thus reducing the effect of evaporation. Sacred pools in the Eastern Cape supply over nine different types of building materials, more than forty medicinal plants, over ten species of fuelwood, a large variety of cultural species, resources with economic value (such as the exotic prickly pear and *Aloe* plants), game meat, honey, clean water, and forage of different densities that attain value at different times in the year and under different drought conditions.

Sacred pools also occur in India. The river pools in the north Indian States of Himachal Pradesh and Uttaranchal are protected because of their religious importance and are called *machhiyal.* Nobody may fish from the *machhiyal* and they thus serve as breeding pools for fishes (India Local).

In Peru, spiritual values and belief systems, including the belief in mountains as living beings and divinities, have allowed for the maintenance of a cultural identity among the Quechua people of the southern Peruvian Andes. This identity manifests itself in a cosmology based on a system of links between the natural, spiritual, and human worlds. Mount Ausangate (6,384 m) is considered to be the main *Apu* (sacred mountain) and protector of all indigenous communities of the southern Peruvian highlands. For the ancient Incas this mountain gave birth to the Urubamba River, the most sacred of all the sacred rivers in Peru, which runs through the Sacred Valley toward Machu Picchu. For contemporary Quechua communities, Ausangate is a powerful Apu that possesses the power of *Camac* (vital energy) and is the lord of all animals, crops, and plants. Its power is recognized beyond the region and it is revered by all Quechua nations in Bolivia, Ecuador, and Argentina. As ecosystem services are diminishing, the spiritual dimensions of the local culture may become the most important mechanism to avert ecological and cultural crisis (Vilcanota).

The practice of nature worship also extends to wooded landscapes. All over India, East Africa, and southern Africa, local people protect patches of forests—sacred groves—dedicated to deities or ancestral spirits. Foresters, travelers, anthropologists, and ecologists have for more than two hundred years described and documented sacred groves—more than 14,000 in India alone (India Local). A single watershed such as the Mala watershed in Karkala Taluk of Dakshina Kannada district of Karnataka state could contain more than 400 such groves. Sacred groves are wooded landscapes containing vegetation and other forms of life and geographical features that are delimited and protected by human societies in the belief that keeping them in a relatively undisturbed state expresses the relationship between humans, the divine, and nature (Hughes and Chandran 1998). Diverse cultures perceive this relationship in different ways, and institutionalize various rules of behavior (taboos) with regard to the sacred space and its elements (Malhotra et al. 2001). Sacred grazing woodland in western Rajasthan, locally called *oran,* are managed and used by local people and constitute almost 10% of the landscape in this semi-arid area (Mitra and Pal 1994). The Bishnoi community in western Rajasthan is known for the conservation practices associated with *orans* such as the protection of *Khejadi* (*Prosopis cineraria*) and the Chinakara deer.

Ecosystem-level conservation efforts like sacred groves and ponds are supported by species-level conservation efforts. In Indian villages, totemic species belonging to subclans, clans, or tribes are only to be hunted by the respective groups, thus contributing to the sustainable use of these species (India Local). In Sweden, institutions originally developed to conserve the Kristianstad Wetlands are spawning other institutions for species conservation; for example, concerted efforts have been made to restore the White Stork population, partly because this species is considered a symbol of the area. Restoration of stork habitats has resulted in an overall increase in biodiversity and also seems to have increased public awareness of natural values in the area (Sweden KW). In the Kat River valley in the Eastern Cape, local people actively conserve valuable species such as *Olea europeae* var. *africana* through local social institutions. These institutions are, however, being eroded leading to a failure of community-based conservation. (See also MA *Policy Responses,* Chapter 14.)

11.3.2 Local Management of Ecosystems

Local management of ecosystems plays an important role in generating services both for local people and for the global good. For example, as described in the previous section, people often manage fine-scaled patches (such as sacred groves and pools, hotspots of soil nutrients and moisture) and narrow corridors that provide critical links between landscapes. In Bajo Chirripó, local communities nurture a mosaic landscape, consisting of sacred places, springs, agroecosystems, and high mountains. Sacred places such as high mountains are a source of faunal biodiversity since indigenous people do not enter unless they have permission from the *awá* (shaman). The Tropical Forest Margins community assessments illustrate how communities manage diversity in tropical forests, thereby contributing to global biodiversity (KM–Tropical Forest Margins). In Trinidad's Northern Range, local people patrol beaches to protect turtle nesting grounds. Whereas previously turtle eggs were harvested for consumption, today protection ensures sustainable income from ecotourism (KM–Northern Range).

Local management, knowledge, and institutions concerning ecosystems are continuously evolving. The community-based assessments illustrate how local management systems can be in various stages of being eroded, adapted, or revived. In Sistelo, Portugal, local ecological knowledge is closely related to agricultural practices. Communities used to harbor extensive knowledge concerning plant species, their medicinal applications, and their effects on soil condition; seasonal and moon cycles and their influence on agricultural crops; and water management techniques. But with improved access to new sources of income, people have become less dependent on local ecosystem services. Most young people in Sistelo now do not have contact with agricultural practices. Today, knowledge that used to be essential for people's survival is almost exclusively possessed by the oldest members of the community (Portugal). In Kristianstad Wetlands, Sweden, farmers' knowledge is being revived through restoration projects of the highly valued flooded meadows and sandy grasslands. Traditionally, these practices were aimed at producing fodder for cattle during winter, but now they are used to enhance biodiversity and other ecosystem services associated with the cultivated landscape (Sweden KW).

Several community assessments illustrate the importance of local people's knowledge to the successful management of ecosystem services. The Sinai Bedouins know exactly how to locate their water harvesting structures, since they know more about the local hydrology than modern engineers (Sinai). Local people in the Laguna Lake Basin know where the best fishing areas are and where to locate rice paddies in relation to the flow patterns of water. Local land tenure systems are adapted to manage these hydrological dynamics (KM–Laguna Lake Basin). In the Eastern Himalayas, local people manage small watersheds and forests and make use of zoning to limit the impact of human populations. In Xinjiang, Western China, local people have elaborate traditional underground water harvesting structures, called *karez*. These 800-year-old systems maintain both water quality and quantity (KM–Western China).

At some critical times, community-based management and local interventions make a big difference. In times of crisis, such as heavy droughts or floods, local adaptations to mitigate the negative impacts of these events provide benefits to the people involved. There are many examples of pro-active local management strategies, many of them based on oral tradition and customs, paying off long after they have been implemented. In that sense, local people both respond to drivers in the short term, and also adopt various adaptive strategies for the long term, for example by implementing management strategies based on long-term learning and experimentation. Such communities increase the

Figure 11.3. Local People Working in the Agricultural Terraces of Sistelo, Portugal (Photo by Henrique Miguel Pereira)

capacity to sustain and manage ecosystems adaptively by learning and constantly developing new responses or reviving earlier experiences.

At other times, however, local management systems have little impact. In several cases, they are dysfunctional, as when local people over-utilize natural resources. In the Eastern Cape province, South Africa, 80% of all medicinal plant species are vulnerable to overexploitation (Dold and Cocks 2002). The PNG, Downstream Mekong, and São Paulo assessments found that many people do not abide by local rules or national laws, and exploit ecosystems for short-term gain (KM–PNG, KM–Downstream Mekong, KM–São Paulo). The bushmeat trade throughout Africa has a major impact on wildlife biodiversity, particularly in forest ecosystems (Barnett 2000). Communities are not always noble managers of ecosystems for the common good. Even if they have the potential to become stewards of ecosystem services and landscapes, they may be overwhelmed by social and economic forces operating at other scales (Lambin et al. 2003). For example, in the Mekong Wetlands, Viet Nam, government policies have promoted the conversion of mangrove swamps to shrimp farms, leading to great losses of biodiversity. In the Eastern Himalayas, economic incentives for private forest owners have led in some instances to deforestation in indigenous forests. As with other user groups, competition, conflict, unequal power relations, and diverging goals and purposes of ecosystem management are common realities.

11.3.3 Cross-scale Interactions and Social Networks

11.3.3.1 There Are No Isolated Communities

No community is isolated from larger-scale processes (MA *Policy Responses,* Chapter 14). These large-scale processes include policies, conventions, funding programs, market forces, tourism, global warming, and mega projects such as large dams and transboundary protected areas. Some have negative impacts; others can be used by communities to improve their well-being.

The ability to cope with, adapt to, and shape change varies among the assessments. In Eastern Himalayas, for example, communities experience a number of negative impacts from external processes. Medicinal plants are overexploited because of the demands created by national and international pharmaceutical interests. Construction of the Teesta Dam Stage IV and the Ramam Hydel Project in the area will result in the submergence of villages and fragmentation of landscapes in Mahanda and Singhalila Wildlife Sanctuaries in India. The Kalikhola Mini Hydro Project in the Singhalila Wildlife Sanctuary may lead to the loss of faunal habitat, causing conflicts between people and problem animals in the villages and subsequent loss of agricultural production, with local people having little influence on this process (Eastern Himalayas).

Bedouin people may become isolated by wars and conflicts, causing them to lose their ability to cope with political and environmental change. The introduction of development projects and factories generates new jobs, but it also affects the Bedouin lifestyle (Sinai). In Papua New Guinea, local people are unable to influence the coral bleaching that is affecting fish stocks (KM–PNG). Communities in the Richtersveld National Park, South Africa, are subject to national and international conservation policies that affect their grazing rights and their ability to move their livestock (SAfMA Livelihoods). These policies, in turn, are influenced by global conservation sentiments and funding. Assessing ecosystems through communities reveals the interconnectedness across scales, as well as the impact on people of decisions and actions taken place elsewhere.

11.3.3.2 The Role of Social Networks

Local communities often lack the capacity to intervene when they are subject to socioeconomic forces that cause ecosystem change. Nested institutions and organizations are therefore important in buffering local people against these forces. Social networks seem to be essential for adaptive management processes; they enhance communities' resilience and well-being. In the Kristianstad Wetlands, collaboration between local steward associations and several administrative levels enables continuous ecosystem management in face of external processes (Sweden KW).

Most communities examined are slowly increasing their networks by linking with NGOs and even government. In the Northern Range assessment, one community successfully resisted a development project by forming a commu-

nity-based organization. At Richtersveld in South Africa, local people successfully incorporated their needs and concerns into the municipality's Integrated Development Plan, started their own conservancy, and eventually claimed back valuable mining land—an accomplishment attributed in large part to their ability to network locally, nationally, and internationally (SAfMA Livelihoods). In Papua New Guinea, communities are being assisted by lawyers and NGOs to sue mining companies for health and environmental impacts (KM–PNG). In Brazil, the Socio-environmental Institute is a good example of a civil movement that has successfully mobilized national and international linkages to achieve its objectives (MA *Policy Responses,* Chapter 14).

Kinship networks also strengthen resilience in several communities. In Lesotho and the Great Fish River, people rely on family members for labor, remittances and social support (SAfMA Livelihoods). Indigenous Fijians have intricate exchange arrangements; sharing with relatives ensures that the resources are efficiently used and that people look after each other in times of need (KM–Fiji). This social kinship system is the safety net that enables people to meet their needs in their sometimes harsh and uncertain surroundings. Bedouins, on the other hand, prefer to live in small groups of five families; this enhances their mobility but has a negative impact on their capacity to cope with external challenges (Sinai).

Key actors that build trust and develop a shared vision are essential for social networks to function (Sweden KW). Opinion leaders in government and in the community can act as agents of change. Where altruistic individuals have catalyzed a community-based process, it has often led to major benefits for ecosystem management. The arrival and departure of these change agents is, however, unpredictable, and many examples exist where charismatic individuals are transferred or promoted by their organizations, or manage to find jobs elsewhere with the skills they gained during their involvement with ecosystem management initiatives. The departure of these key individuals can have unpredictable negative consequences, particularly in cases where no arrangements for succession exist.

Trust is one of the key determinants affecting the ability of local people to create and maintain management functions at the local level. Community assessments in southern Africa found that political upheavals and interventions have affected interpersonal, inter-household, and inter-community trust—and therefore management strategies—over time. These upheavals were precipitated by pre-democratic apartheid (separate development) policies (SAfMA Livelihoods).

11.4 Implications for Policy-making

The community-based assessments illustrate that much more than ecological knowledge and understanding is necessary for strengthening the capacity to manage ecosystems sustainably for human well-being. The social dimension behind management needs to be accounted for as well.

Evidence from the assessments indicates that the effective functioning of community-based management depends on the ability of community members to cooperate with one another toward a common goal, often with a common vision. This ability to organize for collective action has a direct impact on landscape structure and function and the services it generates. However, broader processes of change affect local needs and choices, and thereby community members' activities with respect to ecosystems.

This experience of change in social-ecological systems provides the context for flexible and adaptive responses, particularly during periods of crisis and reorganization (Folke et al. 2003). Adaptive management and governance therefore draws on experience but allows for novelty and innovation. It provides a repertoire of general design principles that can be drawn on by resource users at multiple levels to aid in the crafting of new institutions to cope with changing situations (Ostrom et al. 2002).

A number of examples demonstrate that community-based management is frequently thwarted by creating centralized institutions; it is enhanced by systems of governance that exist at multiple levels with some degree of autonomy, complemented by modest overlaps in authority and capability. A diversified decision-making structure allows for testing of rules at different scales and contributes to the creation of institutional dynamics important in adaptive management and governance.

This is essential in situations where the self-repair and capacity of ecosystems to generate ecosystem services can no longer be taken for granted. A major challenge for management is to develop institutional structures that match ecological and social processes operating at different spatial and temporal scales and addressing linkages between those scales (Holling and Meffe 1996; Folke et al. 1998).

Therefore, an important part of adaptive management and governance is to encourage communities and local organizations to interact with one another and with organizations at other levels (Svedin et al. 2001; Ostrom et al. 2002). Examples from the sub-global community-based assessments illustrate the importance of organizations that bridge communities with other levels of governance, and where social networks and key actors play an important role for successful ecosystem management. Researchers can play an essential role in such bridging processes, as illustrated in the village assessments in India (India Local).

Multi-level governance of ecosystems needs constant adjustment, which requires innovation and experimentation (Shannon and Antypas 1997; Imperial 1999; Danter et al. 2000; Ludwig et al. 2001). Olsson and Folke (2001) describe the development of watershed management by a local fishing association in a multi-level governance system faced with internal and external ecological and social change. The social change included devolution of management rights, which provided an arena for local users to self-organize and to develop, refine, and implement rules for ecosystem management. Not only do these people respond to change, but by doing so, they build adaptive capacity to deal with future change in the multi-level governance system.

Adaptive co-management systems are flexible community-based systems of resource management tailored to specific places and situations and supported by various organizations at different levels (Olsson et al. 2004). They rely on the collaboration of a diverse set of actors operating at different levels, often in networks, from local users to municipalities, to regional and national organizations, and also international bodies. The sharing of management power and responsibility may involve multiple institutional linkages among user-groups or communities, government agencies, and nongovernmental organizations. Adaptive co-management takes place, for example, in the context of the Biodiversity Register program in India (Gadgil et al. 2000; see also Chapter 9) and through the involvement of several local steward associations in the management of the landscape in Kristianstad Wetlands, Sweden.

Threats to co-management include large-scale international programs such as transboundary conservation areas (MA *Policy Responses,* Chapter 14) and top-down development interventions, for example some ambitious agricultural schemes in South Africa's Great Fish River area (SAfMA Livelihoods). Lambin et al. (2001, 2003) provide comprehensive overviews of such interventions and their impacts on resource use patterns and the capacity of ecosystems to generate services.

11.5 Conclusions

Community-based assessments provide lessons for sustainability. Research that carefully records both social and ecological system characteristics, and their interactions over time, will enable role players to develop shared knowledge about the factors that allow some people to sustain ecological systems for long periods of time while others destroy them rapidly.

Community-based assessments should be performed in collaboration with local groups and actors. By conducting assessments in this way, they become relevant to decision-makers at all levels, from the local resource user to people involved in international conventions. While this is not an easy process, it is an essential one. The main incentive for local communities to participate in assessments is improved capacity for ecosystem management at the local level. Most assessments found that this was an adequate incentive for communities to participate, and also that communities that conducted assessments were in a stronger position than before the assessment to raise funds for development projects.

Often ecosystem assessments are done on the biological and ecological aspects first, and then those results are presented to stakeholders for consideration. Community-based assessments bring people and their knowledge and practice into the process as a part of ecosystem management. Here, the experience of communities in resource management is drawn upon as a complement to scientific information.

People generate, accumulate, and store experience and knowledge about resource dynamics. They also draw on knowledge from outside their communities in their resource management. Some communities manage ecosystem capacity, others erode it. Social inventories identify the diversity of actors in the landscape and their use and misuse of ecosystem services.

Communities can act as stewards of ecosystem services and there is potential to redirect incentives and governance to stimulate and enhance this role. Embedded within proper institutional and organizational contexts, rural communities contribute to maintaining the ecological life-support systems on which, for example, urban communities depend. Such stewardship of the landscapes and seascapes needs to be developed, secured, and strengthened.

Therefore, policies and incentives from governmental bodies in urban settings, at county levels, and in municipalities should be implemented to empower such groups and create institutional frameworks that enhance their potential to respond to change without eroding ecosystem resilience. It should be an essential part of any effort aimed at strengthening the capacity to manage ecosystems sustainably for human well-being.

Communities that contribute to managing ecosystems sustainably for human well-being are organized into social networks with trust and a vision for the future and with institutions (formal as well as informal norms and rules) that support and strengthen management. Such communities tend to have social features that make it possible to deal with external drivers and change. One of the most important features seems to be key leaders or stewards who can mobilize trust and incentives among people in the communities. Another factor is organizations that bridge the local community with other scales of organizations. Such bridging organizations serve as filters for external drivers and also provide opportunities by bringing in resources, knowledge, and other incentives for ecosystem management.

Building adaptive capacity in linked social-ecological systems to respond to change now and in the future is a prerequisite for sustainability in a world of rapid transformations (Gunderson and Holling 2002; Raskin et al. 2002). In addition to scientific information, it requires the involvement of resource users, decision-makers, and other interest groups in resource management (Ostrom et al. 1999; Berkes et al. 2003). Ecological knowledge and understanding of resource and ecosystem dynamics among communities, its incorporation into resource-use practices and governance structures, its temporal and spatial transmission and transformation, and its re-creation through cycles of crises and reorganization needs to be nurtured to counteract social-ecological vulnerability. Local communities no doubt play a significant role in this respect.

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Chapter 12

Reflections and Lessons Learned

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Main Messages ***280***

12.1 Introduction **280**

12.2 Sub-global Assessment Process Revisited **281**
12.2.1 Practical Constraints, Adaptive Solutions
12.2.2 Users, Stakeholders, and Reviewers
12.2.3 Assessment versus Research
12.2.4 Learning, Networking, and Capacity-building

12.3 Conceptual Framework Reexamined **283**
12.3.1 Ecosystems and Human Well-being
12.3.2 Drivers and Controls
12.3.3 Use of Scenarios
12.3.4 Challenges in Applying the Framework: Adaptation and Modification

12.4 Issues of Scale and Knowledge Systems **285**
12.4.1 Cross-scale Interactions
12.4.2 Spatial and Temporal Scales
12.4.3 Knowledge Systems

12.5 The View from Below **286**
12.5.1 People in Patchy Landscapes
12.5.2 Finely Crafted Responses
12.5.3 Trade-offs and Substitution Possibilities

12.6 Products, Outcomes, and Lessons Learned **287**
12.6.1 Products and Outcomes
12.6.2 Lessons for Individual Sub-global Assessments
12.6.3 Lessons for Multiscale Assessments
12.6.4 Lessons for the Overall Design of the MA

12.7 Conclusion **289**

Main Messages

The sub-global assessments were one of the most innovative features of the MA. They have provided useful insights on the influence of scale and knowledge systems on the relationship between ecosystems and human well-being. Local assessments highlighted the importance of key relationships between ecosystem services and drivers of ecosystem change that were often not perceived at global scales, especially those related to cultural services.

The MA conceptual framework proved to be useful for many sub-global assessments. As the relative importance of ecosystem services and drivers varied across assessments, the conceptual framework had to be adapted as appropriate to individual assessments. The MA conceptual framework and guidelines for sub-global assessments could be applied broadly in a variety of locations and circumstances around the world, but were used to varying extents depending on the particular context of each sub-global assessment.

Assessments that were led primarily by indigenous communities developed alternative frameworks. Two sub-global assessments used such alternative frameworks, which better reflected the communities' views on the relationship between people and ecosystems, were less centered on purely human needs, and placed greater emphasis on cultural services and the spiritual aspects of human well-being. These modifications and adaptations of the MA conceptual framework are an important outcome of the MA.

Most assessments faced similar practical constraints. The main constraints included limited funding, short time frames to deliver results within the timing of the global MA process, limited capacity to conduct the assessment, and lack of data and information. Some of these constraints were overcome by adopting innovative approaches and sharing lessons across sub-global assessments, which was facilitated by the design and mode of implementation of the MA.

Most sub-global assessments were carried out at a single spatial scale. However, even those assessments conducted only at a single scale considered driving forces, trends, and information from other scales. Nevertheless, since multiscale assessments were not uniformly conducted as originally intended, there may have been missed opportunities to test the importance of cross-scale interactions.

The sub-global assessment process generated a range of products and outcomes, one of which is this volume. Individual sub-global assessments and their separate reports are an important source of information, with products meeting the needs of users of those assessments. Outcomes also include the building of assessment capacity, the development and testing of participatory methodologies for undertaking assessments, as well as the formation of a network of sub-global assessments across the globe. The sub-global assessments are already yielding important results and outputs. Most of their results and impacts, however, will come to fruition in the longer term as on-going assessments are completed and influence future decisions relating to ecosystems and human well-being.

12.1 Introduction

The MA is arguably the most ambitious effort to date that aims to assess the state of knowledge on the complex relationship between ecosystems and human well-being. The process has involved over two thousand natural and social scientists and decision-makers from over 90 countries around the world. Serving as authors, reviewers, and members of assessment teams, these large and growing networks of experts and practitioners have contributed their time and intellectual energies largely on a voluntary basis to this collective enterprise.

From the standpoint of the overall MA process, adopting a multiscale approach through the sub-global assessments offered important benefits. First, it was expected that the overall assessment findings would be strengthened by the sub-global assessments, which would add value to the global understanding of the dynamics between ecosystems and human well-being by reflecting views from different spatial scales. Sub-global assessments provide a grounded perspective on the interactions of ecosystems and social systems at finer scales, while also offering different frames of reference from which global dynamics may be viewed. The expectation was that the view from below would indeed be distinct and more nuanced than the global view. Second, sub-global assessments were also intended to enhance the relevance, usefulness, and outreach efforts of the overall MA process, helping to build wide political support for the MA.

The multiscale approach of the MA was likewise intended to benefit those involved in the sub-global assessments. The MA capacity-building objectives included improving capacity to undertake sub-global assessments in as many countries as possible and improving the use of information from assessments in decision-making. Because the sub-global assessments encompassed some key experimental aspects of the MA, they provided a rich and varied learning experience for those involved. The sub-global assessments tested the application of the MA conceptual framework, to gauge its usefulness for assessments at finer scales in different parts of the world. Along the way, many tools and methods needed to be adapted or developed, posing the challenge of learning-by-doing. Synthesizing and learning from the experiences of other sub-global assessments outside the MA provided substantial additional benefits.

Proceeding from a common conceptual framework, the sub-global assessments set out to find answers to the MA's five overarching questions (see MA Objectives, Focus, and Approach at the beginning of this volume). All sub-global assessments were meant to examine these questions in their particular settings, to adapt them as appropriate, and then to report on the outcomes. It was expected that the answers would differ depending on the diversity of perspectives and knowledge that different users, stakeholder groups, and decision-makers brought to the sub-global assessment process. It was also expected that the answers would vary to some degree depending on the scope and coverage of the assessments—from local, national, regional, and other sub-global scales—when compared to MA findings at the global level.

The initial MA working assumptions or hypotheses included the following:

- The MA conceptual framework and guidelines for sub-global assessments could be applied broadly in a variety of locations and circumstances around the world.
- Findings from the global assessment would inform the sub-global assessments, and vice-versa, for an improved set of assessment findings overall.

- The involvement of different systems of knowledge in an integrated assessment framework is important and feasible and provides significant benefits;
- Funding for sub-global assessments could be secured from a variety of sources, which would strengthen user involvement in each location.
- Engagement with multiple stakeholders/users in each sub-global assessment location defines and drives the assessment process.
- Sub-global assessments can learn from one another and benefit from exchanges on methodologies and lessons learned.

At the start of the MA process, only a small number of sub-global assessments was envisioned. However, at the time this report was being finalized (early 2005), a total of 18 approved assessments, and another 16 associated assessments, were involved in the MA process. These assessments were interested in being part of an internationally prominent undertaking, in using the MA conceptual framework, and in learning from other similar experiences. At the time of writing, only three sub-global assessments were fully completed, with many continuing beyond the timeframe of the core MA process. Nevertheless, the experiences from the sub-global assessments to date already offer many important lessons, and suggest promising directions for future assessments. There remains a high level of interest in undertaking sub-global assessments, even without the possibility of funding from the MA, and even as the MA process draws to a close.

This chapter reflects on these experiences and the lessons learned so far. We revisit the process employed in conducting the sub-global assessments in light of the initial assumptions and the MA conceptual framework. We then examine two of the most innovative features of the MA design, namely, the treatment of scale and different knowledge systems in the assessments. In this chapter, we also take stock of what has been achieved thus far, and offer suggestions for how similar assessments may be designed and implemented in the future.

12.2 Sub-global Assessment Process Revisited

In mostly adopting a ''view from below'' or ''bottom-up'' approach to the selection and implementation of sub-global assessments, the domain and scope of individual sub-global assessments were left to the teams involved in their execution, in consultation with their users and stakeholders. This process generally involved the consideration and congruence of institutional (for example, political governance boundaries) and biophysical factors (for example, the extent of a river basin), and the needs of users and stakeholders of each assessment. All sub-global assessments were asked to use the MA conceptual framework as a starting point, and to assess conditions and trends, scenarios, and response options with respect to the ecosystem services they chose to analyze.

The bottom-up approach led to an uneven distribution of assessments across ecosystems around the globe. For example, there was limited representation of island and marine ecosystems and also few assessments in industrial countries and urban areas. Ideally, the MA Sub-Global Working Group would have designed a set of assessments that would have resulted in better representation of ecosystems and regions, but this was not possible due to funding limitations, time constraints, and variable levels of capacity of assessment teams. (See Chapter 6.) Instead, the Working Group often had to rely on existing initiatives or institutions that were undertaking processes relevant to the MA, which in most cases were then responsible for raising their own funding and conducting the assessments. Since sub-global assessments sought to respond to their users' needs and to their specific contexts, no two assessments were alike, making comparisons across sub-global assessments more difficult, but potentially also more rewarding.

12.2.1 Practical Constraints, Adaptive Solutions

Each assessment was confronted with practical implementation constraints. Common constraints included: insufficient funding; lack of data and information; limited time; and gaps in available capacity to conduct the assessment, including tools and methods with which to undertake specific components of the assessment process.

Keeping users interested and engaged, as well as countering user fatigue, were common challenges. Ensuring that the assessment was shaped around questions and issues of relevance and interest to diverse users, rather than only to scientists, was also critical to maintaining user interest. It is important to recognize that there are real transaction costs, notably in terms of time invested in consultations, in pursuing greater inclusiveness and user participation. For those assessments lacking data and information and technical capacities, however, efforts to include a broader range of perspectives and greater user participation proved to be a logical strategy. In this way, several sub-global assessments were able to generate information, and raise additional resources, while ensuring the relevance of assessment findings.

By necessity, sub-global assessments had to be creative and opportunistic in making the best use of the mix of resources available to them. In most cases, the assessments built on on-going or planned processes, with the MA providing some seed funding and a coherent framework for analysis. But in most instances, the financial contribution of the MA represented a very small percentage of overall funds. Most sub-global assessments started late in the overall MA process because of lack of available funding. A notable exception was the Southern Africa assessment; SAfMA obtained a substantial amount of funds from the MA and was one of the first assessments to get started, led by a team of experienced natural and social scientists.

The need to bring together human, financial, material, and other resources over a short time period encouraged most sub-global assessments to be creative and to employ strategies and methods that addressed different resource needs simultaneously. Many institutions provided in-kind contributions of staff time or office resources, while the activities and outputs of related projects also fed into planned assessment activities.

12.2.2 Users, Stakeholders, and Reviewers

The definitions of stakeholders and users of an assessment can take on different meanings across scales. The MA conceptual framework defined ''stakeholder'' as ''an actor having a stake or interest in a physical resource, ecosystem service, institution or social system, or who is or may be affected by a public policy'' (MA 2003, p. 215). In the MA parlance, ''users'' refers to those decision-makers who will use information from an assessment as they make decisions relating to ecosystems and human well-being. User groups naturally vary across the sub-global assessments, depending on contexts and circumstances. Among some sub-global assessments, the terms ''user'' and ''stakeholder'' tended to be used interchangeably.

Like most global assessment processes, the global MA process was largely driven by groups of individuals linked to academic and research institutions, with the findings targeted primarily at users in governments, international conventions, and multilateral processes. In contrast, while groups from academic and research institutions were active in sub-global assessments, many local-level assessments relied on local users to provide information, with the result that these users were often more directly involved in the assessment process than they would have been otherwise. Furthermore, the definition of users and stakeholders tended to expand or evolve in the course of an assessment, as better understanding of the dynamics of the ecosystems being assessed uncovered new or different sets of users and stakeholders. Therefore user identification and engagement, critical steps in the prescribed MA assessment process, had to be viewed and implemented as an iterative, adaptive process.

Implicit in the MA conceptual framework and assessment guidelines is the assumption that the users, stakeholders, and peer reviewers of the assessment are distinct groups. While users and stakeholders can be more readily distinguished at the global level, at finer scales of assessment, the distinction among them becomes much less clear. In some fine scale assessments, the users, stakeholders, and reviewers could turn out to be from the same group of persons. With regular interaction and involvement of users, stakeholders, and reviewers in the assessment process, the feedback, peer review, and learning loops tended to be considerably shortened. This not only enhanced the credibility and relevance of sub-global assessments, but also fostered a sense of ownership of the assessment results and appeared to help increase commitment to follow-up action.

Teams based in academic or research institutions led many sub-global assessments; examples include the assessments in southern Africa, India, Portugal, and Sweden. These teams were responsible for identifying and involving other local and regional users, who in turn became important providers of knowledge and reviewers of the results. An interesting variation was the Vilcanota assessment in Peru, designed and led by Quechua-Aymara indigenous peoples with little or no involvement from academic institutions. A local NGO provided a bridging mechanism between the MA and local communities, facilitating assessment design and building capacity to undertake the assessment work.

12.2.3 Assessment versus Research

From the outset, the MA was careful to clarify the definition of what an assessment is, noting the difference between research and assessment. The MA defined a scientific assessment to be ''a social process to bring the findings of science to bear on the needs of decision-makers.'' Scientific research, on the other hand, was viewed as a distinct process of data-gathering and hypothesis-testing to advance human knowledge that does not necessarily meet the information needs of decision-makers in direct ways. In the case of the global MA, the assessment process was not meant to generate new data or research findings.

Among the sub-global assessments, however, the lines between research and assessment were blurred in a number of cases. The primary reason for this was the need to fill data gaps, leading a number of sub-global assessments to undertake some research and primary data collection. The lack of historic and comprehensive data was particularly problematic at local scales. In many cases, relevant information was not published, or had not been validated through some form of peer review process. Thus for those instances where primary information was generated through research as part of the assessment process, the MA documentation itself became an important reference for the process.

These efforts to fill in gaps through primary data collection contributed to delays in the assessment timelines and cut into the time needed to do other analysis. As a result, sub-global assessments took longer to complete the full cycle of activities than the time frame originally envisioned in the MA process design.

Nevertheless, the research and primary data collection, as well as collation of existing data, generated important baseline information for many of the assessment sites. For many users and stakeholders, this information base is already an important contribution of the MA to user needs, in addition to other benefits derived from the assessment itself. The baseline information will facilitate future assessments by providing an important benchmark against which future changes in ecosystems services and human well-being can be assessed.

12.2.4 Learning, Networking, and Capacity-building

The common constraints and challenges faced by all sub-global assessments encouraged a spirit of collective learning and mutual support. Learning across sub-global assessments was designed as part of the MA process, including through a series of face-to-face and virtual meetings, opportunities for peer mentoring, facilitated information sharing, and exchange visits. Working group meetings were designed to be not only occasions to exchange information, report on progress, develop products and drafts, but also to build capacity and to cement social and professional networks.

In order to ensure constant exchanges and mutual learning between the global and sub-global assessment compo-

nents of the MA, these activities included members of the global assessment team as well. The formation and meetings of ''cross-cutting'' teams, members of which were drawn from global assessment authors, sub-global assessment teams, and the technical staff of the MA secretariat, meant that information and insights from sub-global assessments were available to the global assessment through these individuals. The cross-cutting approach was meant to help alleviate practical difficulties arising from the fact that the global and sub-global assessments were being conducted in parallel, with most sub-global assessments having started later. In addition, a global–sub-global linkages team was created to further facilitate the inclusion of sub-global material in the global assessment; the team familiarized itself with both the global and sub-global reports, and provided material directly to global and sub-global authors.

Through these mechanisms, even while still on-going, sub-global assessments were able to contribute to the global assessment. For example, the sub-global assessments provided case studies to illustrate the global scenario storylines and helped to define and improve understanding of driving forces and responses considered in the global assessment. At the same time, training workshops and technical assistance provided by the global team, especially in the use of scenarios, were important capacity-building opportunities for the sub-global assessment teams. Despite these mechanisms, however, because of the tight MA timeline, most sub-global assessment results became available too late for the global assessment to make good use of them.

New tools and techniques such as ''knowledge markets'' (see Box 2.1 in Chapter 2) were developed to facilitate faster transmission and sharing of information and insights in the context of conducting an analysis of experiences across all 34 sub-global assessments. Knowledge markets facilitated the efficient exchange of information with the authors of this volume, and newer assessments participating in the exchanges could learn from the experiences of the more advanced assessments. Links among sub-global assessments and between global and sub-global assessment teams were further facilitated by the provision of modest funding for travel, periodic meetings, and telephone conference calls. The considerable technical capacity-building, professional development, and networking that resulted from these activities are among the immediate visible outcomes of the MA. This was especially important for strengthening assessment capacity in developing countries, where 28 out of the 34 sub-global assessments are located.

12.3 Conceptual Framework Reexamined

Agreement to use the MA conceptual framework was a criterion for selection as a sub-global assessment, in order to facilitate comparisons across regions and to ensure that the sub-global assessments contributed to the overall MA process. The conceptual framework proved to be a useful tool for communicating the complex interactions between ecosystems and human well-being, and possible response options, to many different audiences. The MA sub-global assessments used the conceptual framework to different extents, depending on their particular circumstances and contexts. Beyond the MA and its sub-global assessments, the conceptual framework was also used in academic institutions and by teaching professionals. The opportunity to learn from and apply the MA conceptual framework was among the commonly cited reasons for wanting to join the MA process.

12.3.1 Ecosystems and Human Well-being

The MA conceptual framework is deliberately centered on humans, and was designed to explore the links between ecosystems and human well-being. The underlying premises are that ecological and social systems are coupled, and that the flow of ecosystem services and human well-being are linked and interact in complex ways. Human well-being—which consists of environmental security, basic materials for a viable livelihood, freedoms and choice, health and good social–cultural relations—critically depends on, and at the same time affects, ecosystem services. The relationship of ecosystems and their services (provisioning, regulating, supporting, and cultural) to human well-being varies over space and time. However, human well-being includes many aspects not directly based on ecosystem services, and the constituents of well-being are experienced and perceived differently across cultures and socioeconomic levels.

Among the ecosystem services, sub-global assessments tended to focus on provisioning services. Among the dimensions of well-being, freedoms and choices (the ability to influence decisions regarding ecosystem services and human well-being) were the least explicitly addressed in the assessments. This was partly due to the difficulty of assessing the link between freedoms and choice and ecosystem services, given data constraints and the lack of technical skills and analytical tools to conduct this analysis.

However, the consideration of freedoms and choice did come into play in many assessments that sought to enable certain groups to manage their own resources and make important decisions. This was the case, for example, with the Vilcanota, Bajo Chirripó, San Pedro de Atacama, and two Indian assessments. In fact, in any assessment that had strong and broad user engagement, the reconfiguration of freedoms and choice for different stakeholder groups was a theme in the overall process. This highlights a difference between the sub-global and global components of the MA; while the global assessment could only assess aspects like freedoms and choice, the sub-global assessments could actually help to broaden the range of freedoms and choice, for some stakeholder groups at least, through the design and implementation of the assessment process itself.

Among ecosystem services, cultural services also proved difficult to assess. Recognizing and evaluating the condition of the cultural services of ecosystems was a novel feature of the MA. Cultural services are defined in the MA framework as the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences (MA 2003). These experiences include cultural diversity, spiritual and

religious values, knowledge systems, social relations, sense of place, recreation and ecotourism, as well as educational and aesthetic values. Given how varied cultural services are, perceptions of these services will vary across individuals and communities.

Except for tourism, which was one of the easier cultural services to quantify, cultural services were generally underrepresented in the sub-global assessments. The definitions of cultural services, the sub-categories of these services, and the boundaries between these services were unclear. For example, the Vilcanota assessment could not relegate the worldview and cultural practices of the Quechua people to the category of "cultural service" and sought instead to center the assessment on culture and spirituality. Apart from the uncertainty associated with the definition of various cultural services, there is a general lack of appropriate data, indicators, and tools with which to assess them. Most of the assessments of these services relied on qualitative descriptions and expert opinion. These forms of knowledge were also somewhat difficult to fit into the assessment.

12.3.2 Drivers and Controls

The characterization of drivers of ecosystem change as being either direct or indirect, and at the same time either exogenous or endogenous, is one indication of the conscious attempt within the MA to bridge disciplinary divides between natural and the social sciences. Ecologists and biophysical scientists in the assessment teams tended to view drivers or driving forces for change as being either direct or indirect, while social scientists, particularly economists, tended to view them as endogenous or exogenous to the decision-making context.

Identification of drivers was challenging because of the complexity of the many factors that together interact to bring about ecosystem change. Sorting through direct and indirect drivers requires both a good understanding of the dynamics of ecosystem change, and a great deal of data and information. Important drivers may be omitted or overlooked simply because the data are not available. One clear lesson is that the identification of driving forces requires an iterative learning approach. As the assessments progressed, the specific driving forces, how they interact, and how they change over time, became clearer to the assessment teams. Hence the understanding and identification of direct and indirect drivers tended to evolve in the course of the assessment.

Likewise, the classification of drivers as being exogenous or endogenous is not always straightforward, since the scales and boundaries of analysis determine what is endogenous and what is exogenous. The degree of controllability of a driver from the standpoint of actors or decision-makers, and hence their capacity to effectively respond to the driver, also influences the endogenous/exogenous classification. Thus in certain assessments, some drivers were classified as being both endogenous and exogenous, indicating that the decision-maker at the given scale only had partial control over those drivers. However, the controllability of drivers from the point of view of decision-makers and those participating in the assessment can be changed. Capacity-building, networking, and alliances can strengthen the capacity of actors and decision-makers to exercise control and to more effectively respond over time.

12.3.3 Use of Scenarios

Scenarios can provide a way of making structured comparisons of management and development strategy options for ecosystem services. Scenarios can also be, and were used as, multi-purpose tools in the sub-global assessments. In some assessments, scenarios were treated as a tool for communication with local decision-makers. Few sub-global assessments conducted scenarios in the sense of a comparison of alternative futures, and those that did adopted a range of methods for doing so.

Most sub-global scenarios were not linked to the global MA scenario storylines. Though aware of the scenarios developed for the MA global assessment, most sub-global assessment teams explicitly opted to focus first on the needs and issues in their assessments, rather than to be overly bound by the directions taken by the global scenarios. In some cases, the long-term hopes and expectations expressed by users and stakeholders, and embodied in their scenarios, did not necessarily proceed from current short-term trends observed at those levels. The sub-global assessments had limited capacity and experience to undertake scenarios; they also had little opportunity to benefit from the scenarios methodology at the global level, because the global scenarios methodology was evolving at the same time.

12.3.4 Challenges in Applying the Framework: Adaptation and Modification

All the sub-global assessments found the MA conceptual framework to be useful as an initial reference point and guide. Nonetheless, sub-global assessments faced several difficulties in applying the framework in their work. Many assessments, including SAfMA, found it difficult to communicate the concepts at the local level without adapting them to local terms and conditions. Furthermore, language proved to be a barrier in some cases, and the role of institutions and people able to understand the framework and translate it to the local context became important.

Despite having the common conceptual framework and broad guidance on the core elements of the MA process, the sub-global assessments employed a wide variety of approaches and methods, which generated a vast and richly textured information and knowledge base of relevance to assessment users. However, this also limited the comparability of findings across the sub-global assessments, and between sub-global and global components of the MA, or at least made comparison more difficult than it would have been with strict compliance with a common framework and methods.

In conducting their assessments, only a handful of sub-global assessments were able to comprehensively address the elements identified in the MA conceptual framework. For example, most assessments measured the condition of the

subset of services they focused on, but not all of them analyzed direct and indirect drivers of ecosystem change.

One of the most interesting results was the adaptation of the MA conceptual framework in two assessments led and implemented by indigenous peoples in Vilcanota, Peru, and Bajo Chirripó, Costa Rica. In both cases, the MA framework was considered to be overly human-centered, in contrast to the cosmovision of these indigenous people, where the concept of reciprocity between humans and other elements of the environment has traditionally promoted the sustainable use of resources within communities. The resulting adaptations, presented in their reports and discussed earlier in this volume, are an important contribution and provide a useful counterpoint to the MA conceptual framework.

12.4 Issues of Scale and Knowledge Systems

The MA process differed from other scientific assessments in that it set out to assess interactions between ecosystems and human well-being at different scales through the inclusion of sub-global assessments. Another notable feature of the MA was its attempt to incorporate different systems of knowledge into the assessment process.

12.4.1 Cross-scale Interactions

The MA was designed as a multiscale assessment from the beginning, but this proved harder than expected to implement, as it entailed not only undertaking assessments at different scales, from local to global, but also examining the importance of cross-scale interactions on changes in ecosystem services and human well-being.

Except for SAfMA and Portugal, the other sub-global assessments were carried out at single spatial scales, such as that of a single city or region of a country. Except for the two mentioned, conducting nested assessments as initially envisioned in the MA design was not possible because of time and funding constraints, the lack of preparedness to undertake assessments in initial focal regions, and the opportunistic approach most sub-global assessments had to take. From the outset, the MA design recognized that methodologies for conducting multiscale assessments had to be developed further by the sub-global assessments, which proved to be a challenge for these assessments in practice. Nonetheless, each sub-global assessment factored in information and views from other scales as part of their assessment. In that sense, even those assessments conducted at a single scale had multiscale interactions embedded in their analyses. The role of individuals and organizations that functioned as ''sense-makers'' and translators of information from one scale to another proved to be an important link across different scales. (See the discussion on bridging organizations in Chapter 9.)

Through the incorporation of selected information from other scales, it was possible to consider driving forces and information emanating from multiple scales, and to derive useful results for sub-global assessment users and stakeholders. However, the lack of actual ''nesting'' of the assessments did not allow for explicit analysis of cross-scale interactions among some elements of the MA framework, which some global-level audiences had expected the sub-global assessments would deliver. In this case, there was clearly a mismatch not only between user needs and expectations at the global and sub-global levels, but also between the global MA expectations and the resources (funds, time, capacities, data) made available to the sub-global assessments.

One notable exception was the southern Africa assessment, which had an early start and the fewest resource constraints compared to other sub-global assessments. SAfMA included analysis for an entire region covering several countries, two river basins, and some local assessments within these basins. This type of comparison proved to be invaluable and enabled the assessment of the relative importance of services and drivers as a function of scale. Analysis of cross-scale interactions in SAfMA highlighted important implications for decisions and management in the region.

12.4.2 Spatial and Temporal Scales

Another key element of the MA conceptual framework was the consideration of both spatial and temporal scales in the analysis. Drivers and their impacts on ecosystems and human well-being operate at different time scales, from a few days to decades, or even longer. (See Chapter 7.) The conceptual framework also presented a hypothesis regarding the possible relationship between spatial scale and temporal scale. (See Chapter 4.) However, most sub-global assessments focused on spatial scales, devoting comparatively little effort to the explicit analysis of different time scales. This was largely due to the lack of time series data available to most sub-global assessments.

12.4.3 Knowledge Systems

The MA recognized from the outset that taking account of different knowledge systems is important in carrying out an assessment of ecosystems and human well-being. This is easier said than done, and proved to be quite challenging. There were at least two different dimensions of bridging knowledge systems that the sub-global process attempted to address: bridging social and natural sciences, and bridging ''scientific'' knowledge and local and traditional knowledge.

The MA sought to bring together natural and social scientists from the outset. The MA Assessment Panel and MA Working Groups were established with deliberate attention to ensuring disciplinary balance, and most sub-global assessments adequately took into account both the natural and social science perspectives throughout the process. The different disciplines involved contributed a variety of approaches, where the debates, common understandings and workable solutions developed fostered significant cross-disciplinary learning and enriched the process overall. The outcomes of the MA are stronger as a result.

The MA also attempted to bring together local and traditional ecological knowledge and scientific knowledge. The challenge was to try and combine these different types of knowledge in ways that could yield the best possible as-

sessment. One important outcome of the MA, particularly in the Vilcanota, Bajo Chirripó, and Indian assessments, is the documentation and review among the communities of their own knowledge, which has been largely transmitted orally and not recorded.

Local and traditional knowledge added significant insight to the sub-global assessments. There was also no doubt that using local knowledge in local assessments enhanced the credibility of the assessments at the local level. However, the extent to which local and traditional ecological knowledge contributed to the assessments was variable due to local contexts, predisposition and expertise of the assessment teams, and the resources allocated to understanding and using such knowledge. Moreover, incorporating these systems of knowledge into the MA proved challenging because of differences in data, methods and processes for expression, documentation, and validation among knowledge systems.

One of the important steps taken by the MA as an input to the sub-global assessments was the organization of a conference on Bridging Scales and Epistemologies in Alexandria, Egypt, in 2004. The conference brought together many sub-global assessments and other people and initiatives working on issues of scale and knowledge systems at both practical and conceptual levels. Many on-going assessments benefited from the conference discussions that ideally would have been held as the sub-global assessments commenced their work, but the conference had been postponed due to the SARS outbreak in China, where it was originally scheduled to be held. Nonetheless, it was helpful in catalyzing new thinking and reflection and brought added expertise to the MA through new reviewers identified through the conference.

12.5 The View from Below

The view from below is not just a microcosm of the global view, nor is it necessarily framed relative to the global perspective. We found that most sub-global assessments were carried out taking into account their particular scale, issues, stakeholders, and final users, with relatively little input from the global process. Indeed, our findings indicate, as expected, that sub-global perspectives provide markedly different ways of framing and understanding the dynamics between ecosystems and human well-being. Sub-global perspectives also open up myriad opportunities for more finely crafted and better-targeted ways of addressing issues.

12.5.1 People in Patchy Landscapes

There is a significant degree of heterogeneity and patchiness in landscapes, in the conditions of their component ecosystem services, in the driving forces of ecosystem change, and in the possible responses and envisioned futures of people in these landscapes. This heterogeneity can depend on the scale of the assessment, with greater heterogeneity expected in coarser scale assessments. However, even community assessments exhibit this heterogeneity.

Heterogeneity is generally found in the assessment of ecosystem service conditions when viewed at sub-global levels, but much detail on this patchiness can disappear once aggregated at the global level. When the condition of services is averaged across an entire assessment area, there is a tendency to get intermediate values implying similar conditions over the entire area. In most cases, the variance in services may be as important, if not more important, than the average values.

In some cases, ecosystem services that are in critical condition at the local level are missed at the global level because of the process of averaging. The localized scale of the assessment of condition may be too fine for it to show up at the global scale. Similarly, the lack of data on particular threats and drivers (such as degradation, alien invasive species, climate change) often serves to underestimate threats in the region, resulting in overly positive assessments of the conditions of ecosystem services, which may in fact be under critical threat or undergoing rapid change.

12.5.2 Finely Crafted Responses

There has been a tendency to tailor policy responses to the ''average'' assessment, often leading to inappropriate prescriptions and actions. The findings from the sub-global assessments suggest that responses must recognize spatial heterogeneity in the landscape and be crafted at the finest appropriate scale. In reality, people using and managing ecosystems in these landscapes have varying degrees of capacity to exploit the patchiness and variation across their landscape, and to develop adaptive responses and coping mechanisms to meet their needs. Hence from the standpoint of local ecosystem service users, especially in the short term, the conditions of some ecosystem services may not be as critical as the global assessment may indicate.

Responses to changes in ecosystems and human well-being at the sub-global level are somewhat different from responses observed at the global level. While economic incentives provide the context for responses at regional or national levels, they are rarely used in isolation. Considerations such as security can be more important than economic incentives, and intangible benefits can be just as powerful as tangible benefits in motivating responses. The most common responses observed in the sub-global assessments employed organizational and institutional devices, that is, formal and informal measures based on multi-actor collaboration. Examples of this include responses based on collaboration between different levels of government and local actors. Indeed, vertical collaboration among different actors and stakeholders tends to characterize effective responses. (See Chapter 9.) This is because there are many stakeholders with legitimate claims to manage ecosystems, and they tend to have different objectives. Unless they reach a workable agreement (through top-down or bottom-up processes), conflicts are likely to impede actions and come in the way of effective responses.

Responses employed or favored at the sub-global level tend to be calibrated to account for what can be decided and controlled by actors at the level considered. Individual responses themselves also tend to be finely crafted and tuned to specific conditions and driving forces in specific locations

and contexts. There is a marked tendency for actors initiating a response to match their actions with the geographic reach of the drivers they seek to address. Where decision-makers at a given scale only have partial control over the drivers, concerted responses involving actors at different scales tend to be the more effective option.

It is inappropriate to make generalizations about the dynamics and driving forces of ecosystem change, and to intervene on the basis of these generalizations. Drivers are scale-dependent; they operate differently at different scales. To be able to construct effective responses, drivers must be understood. If the goal of an assessment is to formulate global policy, then it is essential to do the assessment at the global scale. There are also multiple channels through which the influence of exogenous drivers is transmitted to the local level. Some global-scale driving forces can cause changes directly at the local scale. Others interact with national-level drivers and together cause local ecosystem change. National-level drivers can also cause local ecosystem change independently of global drivers.

Our findings indicate that the dynamics and driving forces of ecosystem change differ across assessments. Drivers act and interact in very distinct, often synergistic ways in different regions and locales. In the sub-global assessments, individual drivers were rarely identified as important in isolation, nor was any single driver of equal relevance across the assessments. Some driving forces take a long time to unfold, or only become apparent at a coarser scale. The trends in these slow drivers may not be readily apparent at local scales, and therefore may not be factored into local responses. On the other hand, even when drivers are well-understood, actors may still not put in place effective responses. This typically occurs in the absence of actors or organizations that perform the function of linking and coordination of different stakeholders' actions (see Chapter 9) to achieve some degree of collaboration.

12.5.3 Trade-offs and Substitution Possibilities

Trade-offs and substitution possibilities become visible at the local level. The sub-global assessments provided many examples of trade-offs among ecosystem services. Enhancements in some services often came at the expense of other services. In particular, increasing provisioning services from ecosystems typically meant a reduction in the ecosystem's regulating and supporting services. Examples include the adverse impacts of agricultural intensification on water provisioning and soil regulation services, such as in the Mekong delta of Viet Nam (Downstream Mekong), and the loss of supporting services due to mining and the use of mangroves for building materials and fuel, such as in Papua New Guinea (PNG).

These trade-offs among ecosystem services, however, may not necessarily translate directly into impacts on human well-being, because of the possibility of substitution. General improvements in well-being can occur despite decreases in ecosystem services, at least at the local scale. This is because of the possibility, within certain limits, of substitution among ecosystem services and among components of well-being. The widening geographical reach of communities that often accompanies increases in well-being enables them to obtain the services they need from non-local sources. The globalization of trade has facilitated this and has progressively increased the spatial disconnect between human well-being benefits and ecosystem impacts.

However, substitution is possible only within certain limits in time and space; while possible for individuals, it is not always possible across all individuals at higher levels of social aggregation. Improvements in the well-being of particular individuals or communities may involve declines in the well-being of others.

Different communities and societies are organized in different ways to decide what is acceptable and to manage trade-offs among elements of human well-being, with significant consequences for ecosystems. While it may be possible for communities and societies to substitute and trade off elements of well-being, it is not certain to what extent and for how long ecosystem services are substitutable. The degree of equity in access to ecosystem services, and the systems of knowledge that are brought to bear on their management, can have profound impacts on ecosystems and their services. How these play out are integrally linked to the issue of who gains and who loses access to ecosystem services, and how these gains and losses are distributed over time and space in the process of both ecosystem and social change.

12.6 Products, Outcomes, and Lessons Learned

The sub-global assessment process was an important innovation of the MA, and a number of adjustments had to be made in the course of its implementation. A variety of products and outcomes have been generated, and more are expected in the coming years. In the process, we have learned some important lessons relevant for individual assessments, for the organization of sub-global assessments as a group, and for the overall design of future assessments similar to the MA.

12.6.1 Products and Outcomes

Most global assessments, including the global component of the MA, have focused on producing synthesis reports, with their findings as their main outcome. In this regard, the reports from the individual sub-global assessments, which are summarized as individual 30-page peer-reviewed reports, are a comparable result. Each of these reports contains a wealth of information regarding the condition of ecosystem services, scenarios, and response options, focused on their particular setting. This volume, aimed at providing an overview of the sub-global process and lessons learned, together with some comparisons and emerging patterns observed to date, is another significant product. In addition, an edited volume, consisting of selected papers from the 2004 MA conference on Bridging Scales and Epistemologies, is forthcoming.

The sub-global assessment process has led to the development of new tools and methodologies and the collection and generation of baseline information. It has also moti-

vated and facilitated the establishment of governance mechanisms for sub-global assessments that have contributed to the empowerment of stakeholders and users.

The sub-global assessments have yielded a number of other tangible and intangible outcomes. Some of the most important results are less tangible, but no less observable. The capacities that have been developed to lead and undertake MA-type assessments are expected to enhance the potential for further impacts in the future, beyond the completion of the MA sub-global assessments. These capacities are likely to be reinforced by the networks of institutions and professionals that have been developed in the course of the MA.

12.6.2 Lessons for Individual Sub-global Assessments

The sub-global assessment process was a rewarding experience that involved a broad range of stakeholders from different parts of the world. This volume reflects the final results of the completed sub-global assessments and some of the preliminary results from the other on-going assessments. Since many sub-global assessments have yet to be completed, it is clear that most of the substantive results and long-term impacts are yet to come. Nonetheless, there are already clear lessons for future assessments.

Some of the important recommendations for institutions and individuals interested in starting sub-global assessments include the following:

- Securing adequate funding early in the process is essential. The MA provided seed funding for many assessments, but many subsequently had difficulties securing additional funds to undertake complete assessments.
- Significant effort is necessary for engaging with users and stakeholders, and this needs to be an iterative process that may bring in new actors in the course of the assessment.
- Strong leadership with adequate institutional support is important for a successful assessment.
- Learning from other past and on-going assessments can be very useful, as they may have developed innovative tools and methodologies. Reports can be helpful, but can never fully replace personal interaction, especially in the assessment sites.
- Sub-global assessments take time to complete, as they need broad consultations with a range of stakeholders, and in many cases also need to document or generate additional information.
- Extra care should be taken to avoid raising unrealistic expectations. Assessments are important exercises that can reveal many gaps in knowledge and identify a range of possible response options; but they cannot offer magical solutions to local problems.

12.6.3 Lessons for Multiscale Assessments

The substantive findings from the sub-global assessments provide different, more nuanced perspectives on ecosystem services and human well-being interactions than global studies. Sub-global findings also indicate that ecosystem services, drivers, and response options can change with the scale of analysis. It is at local scales that many of the impacts of drivers of ecosystem change are seen and have the most direct effect on livelihoods.

Some lessons for organizing and implementing groups of multiscale assessments, such as the MA sub-global assessments, include:

- A more rigorous approach to selecting assessments could ensure better geographical coverage and representation of ecosystems, but should be balanced with the opportunities for creativity and innovation arising from a more open and ''bottom up'' selection process.
- Focusing on a smaller set of services across assessments would enable better comparative analysis, but must also recognize the particular needs of user groups in each assessment.
- Training and capacity-building in tools and methodologies (ideally provided early in the assessment process) is essential, especially in the development of scenarios and the conduct of multiscale assessments.
- Whereas a more rigid methodology and protocol may better meet analytical needs for multiscale analyses, a more flexible approach is often necessary to accommodate or adapt to different stakeholders from different scales.
- Conducting full multiscale assessments can improve the overall assessment findings, but is resource- and time-intensive. Depending on the goals of the assessment, full multiscale assessments may or may not be warranted.

Few sub-global assessments were full multiscale assessments. Most were conducted at one or two scales, but accounted for and analyzed cross-scale effects. Nevertheless, the use of approaches and analytical tools to account for cross-scale interactions and comparisons could have been strengthened. Some of the more interesting questions relate to the use of variables across scales and the impacts of external drivers on scenarios and response options. Specifically, cross-scale analysis and comparisons can be strengthened by:

- defining and adopting clear methodologies for cross-scale comparisons, and
- including a larger number of regional (intermediate) scale assessments that can bridge local and global processes.

12.6.4 Lessons for the Overall Design of the MA

The inclusion of sub-global assessments no doubt enriched the MA. Future global assessments should continue to feature sub-global components, as appropriate to the goals of the assessment and with some modifications based on lessons learned.

A key lesson is that a clearly articulated and well-understood conceptual framework is important as a common starting point. However, while strict adherence to the conceptual framework would have facilitated analysis and synthesis of results across sub-global assessments, it would have prevented the expression of alternative frameworks that can more appropriately represent the perspectives of local assessment users and stakeholders. Strict adherence to the MA

conceptual framework and implementation guidelines would also have meant giving up the richness of the information and insights generated from adaptations and modifications to the framework.

In retrospect, the sub-global assessments could have been strictly used by the MA to analyze the interactions between components of the MA conceptual framework in different sociopolitical and ecological contexts. In order to do this, the procedural criteria of the Sub-global Working Group would have had to be more strictly followed, and the assessment sites selected in a ''top-down'' manner to ensure a multiscale, nested assessment design. Assessments could also have been chosen for the specific analysis of particular components of the MA conceptual framework. For example, areas that are strongly affected by specific indirect drivers (such as rapid demographic changes in Southeast Asia, sociopolitical changes in the former Soviet Union, or changes in cultural and religious values in Bhutan) could have been selected in order to link these indirect drivers to direct drivers of change. While this more directed, top-down approach would have facilitated comparison and input to the global MA process, it would have constrained the ability of the sub-global assessments to respond to the needs of their users and stakeholders, where these were not congruent with the needs of the MA. It would also have weakened the prospect of securing local support and contributions to the assessment.

Another important lesson is the need to carefully design the sequence of global and sub-global assessments, and to adopt realistic timelines for implementation. For reasons already discussed, most sub-global assessments took longer than expected to get started and will yield many important results only after the main findings and reports of the MA are published. On hindsight, the parallel implementation of global and sub-global assessments was a structural weakness in the MA design that limited the scope of sub-global assessments to deliver on their potential to substantively and qualitatively improve global assessment results. In this regard, it would have been better to stagger the operations of the MA sub-global and global assessments by a couple of years, so that the global assessment could have benefited from the outcomes of the sub-global assessments.

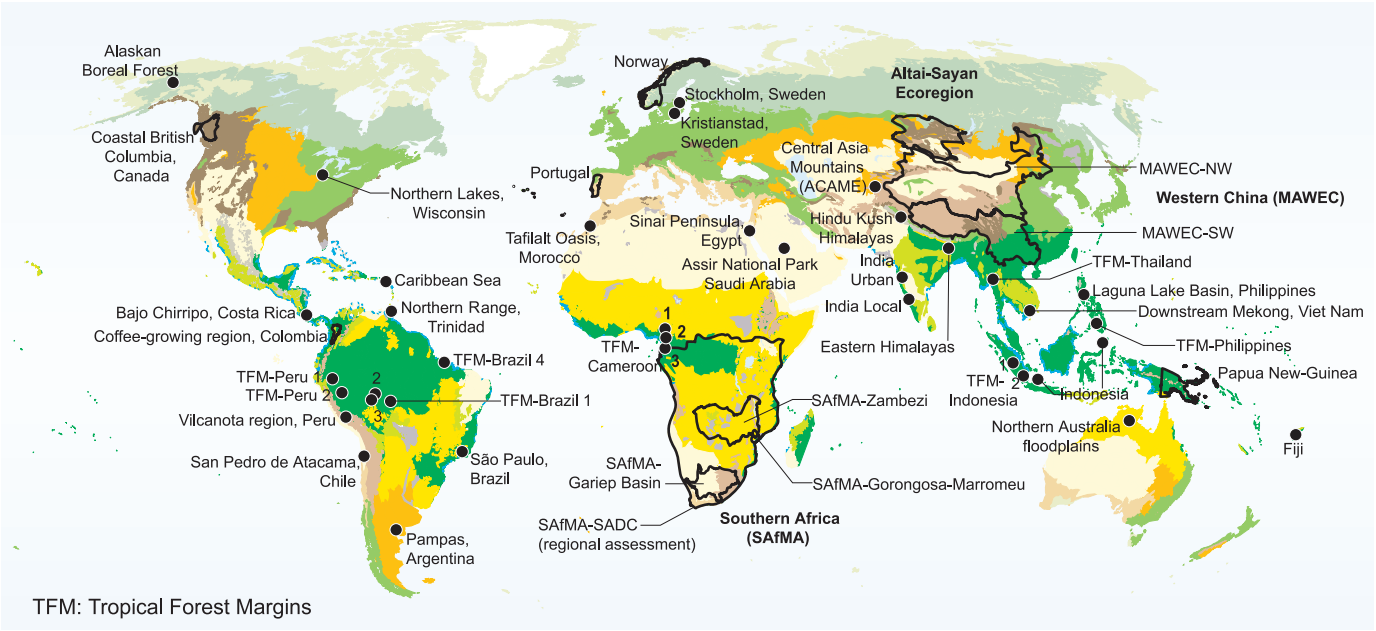
12.7 Conclusion

The inclusion of the sub-global assessments in the MA design engendered a sense of excitement and mobilized stakeholders that would otherwise have been disengaged from international scientific assessments. In the process, it broadened the range of stakeholders involved in the MA, and enhanced the credibility and relevance of the MA itself. The MA has served an important function in bringing together a disparate group of institutions and people from across the globe to focus on ecosystem services and human well-being. The networking and the interdisciplinary professional connections that have been forged across different regions of the world in the course of the MA represent major social capital formation in the international scientific community. It is important to highlight the high level of participation of scientists and professionals from developing countries, where ecosystems and their services are especially critical for advancing human well-being and development. The significant human and institutional capacity-building that has resulted from this process is expected to continue to lead to further advances in thinking and understanding of interactions between ecosystems and human well-being, and in the design and conduct of future assessments. This will continue beyond the life of the MA, and is already stimulating new initiatives and spin-off activities around the globe.

In closing, we would like to thank all the participants in the sub-global assessment process for their contributions and active engagement in this experiment. We have developed and tested new concepts and ways of working, compared ideas, shared lessons, and learned from one another. The diverse array of places, human activities, institutions, ecosystems, ecosystem services, and development issues analyzed as part of this process are a microcosm of the complex realities, trade-offs, and choices we face. We trust that the sub-global assessments initiated as part of this experiment will have begun in some way—and will continue—to contribute to improving decisions and actions affecting ecosystems and the well-being and livelihoods of people into the future.

Appendix A

Color Maps and Figures



Biomes

- Tropical and sub-tropical moist broadleaf forests
- Tropical and sub-tropical dry broadleaf forests
- Tropical and sub-tropical coniferous forests
- Temperate broadleaf and mixed forests
- Temperate coniferous forests
- Boreal forest/taiga
- Tundra
- Mediterranean forests, woodland, and scrub
- Tropical and sub-tropical grasslands, savannas, and shrublands
- Temperate grasslands, savannas, and shrublands
- Montane grasslands and shrublands
- Flooded grasslands and savannas
- Mangroves
- Deserts and xeric shrublands
- Rock and ice

Figure 2.2. Locations of MA Sub-global Assessments. The map shows the locations of the MA sub-global assessments, with areas of coverage where geographical coordinates were available, in relation to the WWF ecoregions.

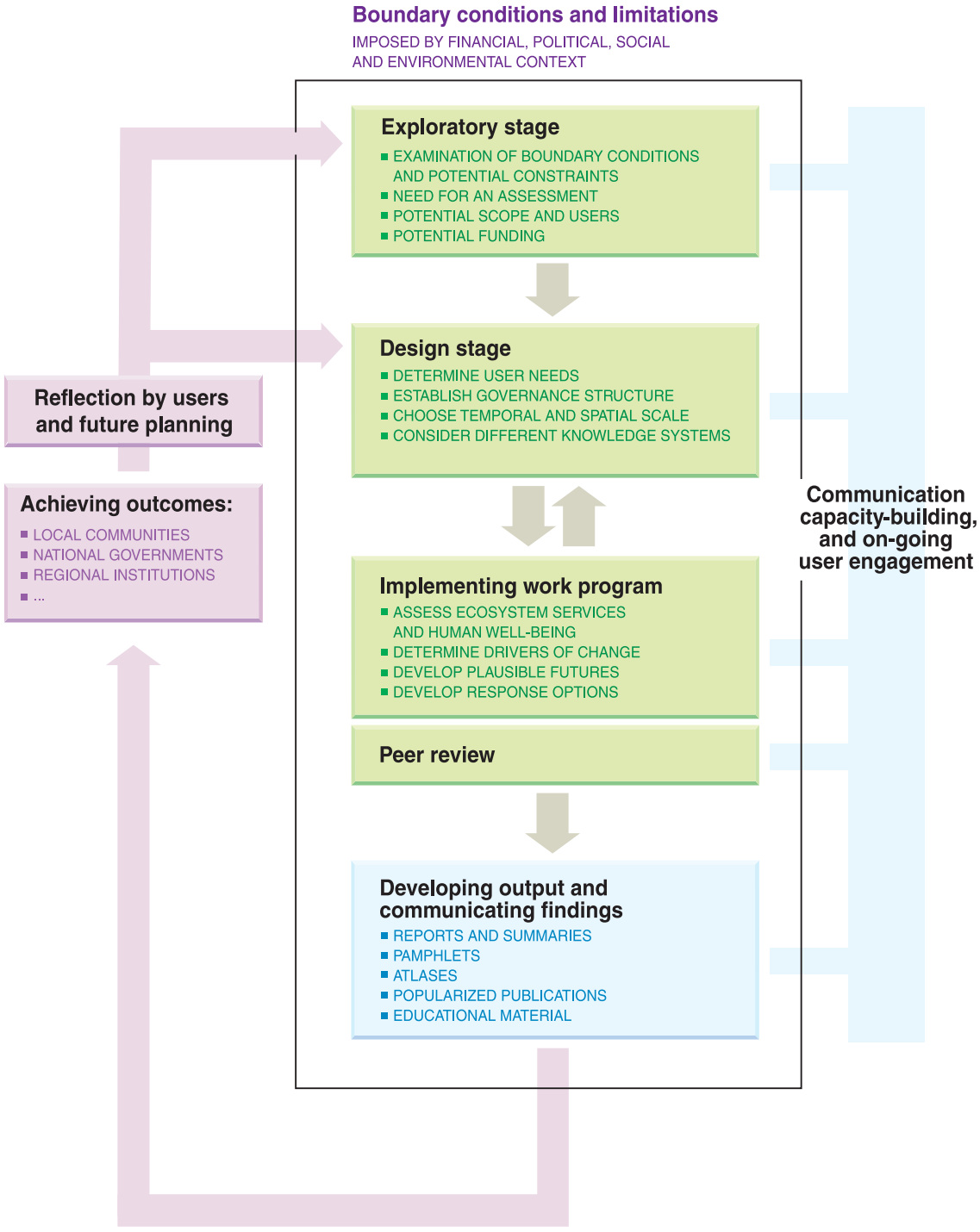


Figure 6.1. Overview of Assessment Process. The sub-global assessment process has three stages that are generally sequential, but often overlapping and iterative: (1) the exploratory stage, (2) the design stage, and (3) implementation of the workplan. The exploratory stage includes an examination of the social, political, and environmental contexts in the areas to be assessed (external boundary conditions), and the resource and human capacity of the assessment team (internal boundary conditions). A fourth set of activities, which includes ongoing user engagement and communication, occurs throughout the entire process. User engagement begins when the assessment is initiated, but communication with users is ongoing in order to maintain user interest, adjust the process to evolving needs, and ensure uptake of the findings. A review process is strongly linked to the implementation of the workplan, and contributes both to the robustness and credibility of assessment findings, and to communication with the users. Final assessment findings are communicated to the intended users and wider audience through the development of appropriate outputs. An assessment should not be seen as an isolated activity; users and technical teams should reflect on the process once it is over, suggest improvements, and determine future assessment needs.

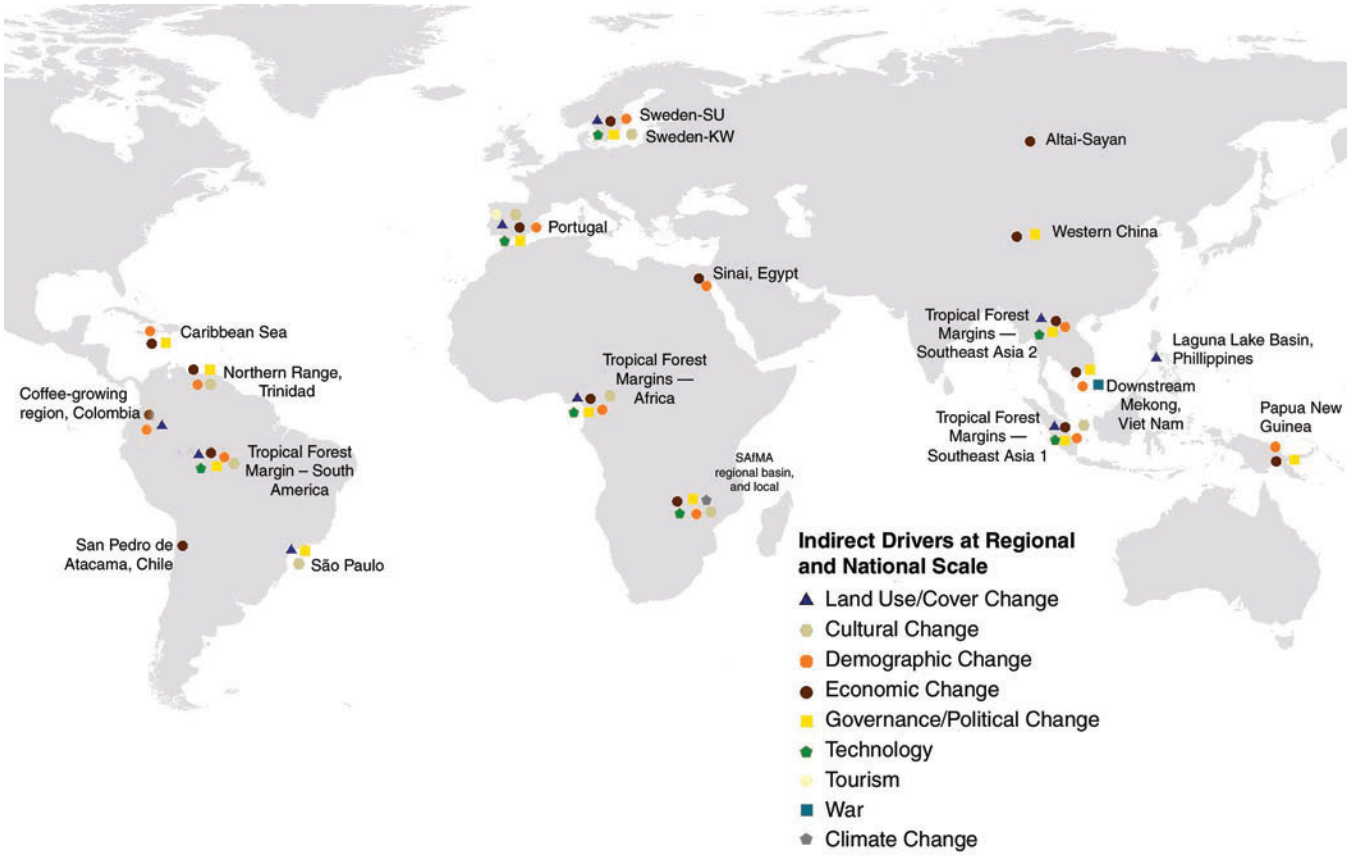


Figure 7.1. Indirect Drivers of Ecosystem Change at Regional and National Scales Identified by the Sub-global Assessments. Land use and land cover change include transformation, ownership, tenure, and regulations that affect terrestrial or freshwater systems. Cultural change includes environmental awareness and attitudes and social capacity. Demographic change includes economic growth, markets, and trade. Governance and political change includes policies, institutions, and legislation. Technology includes innovations in science and technological applications to ecosystem services. Assessments that identified a single driver (San Pedro Atacama, Chile, Altai-Sayan, and Laguna Lake Basin) did not indicate that this was the sole driver of change influencing ecosystem services, but rather that it was the only driver that was assessed, either because of a lack of information about other drivers or because of the particular focus of the assessment. Other assessments concentrated on a wide range of drivers (e.g., Tropical Forest Margins, SAfMA, Portugal, Sweden SU and Sweden KW).

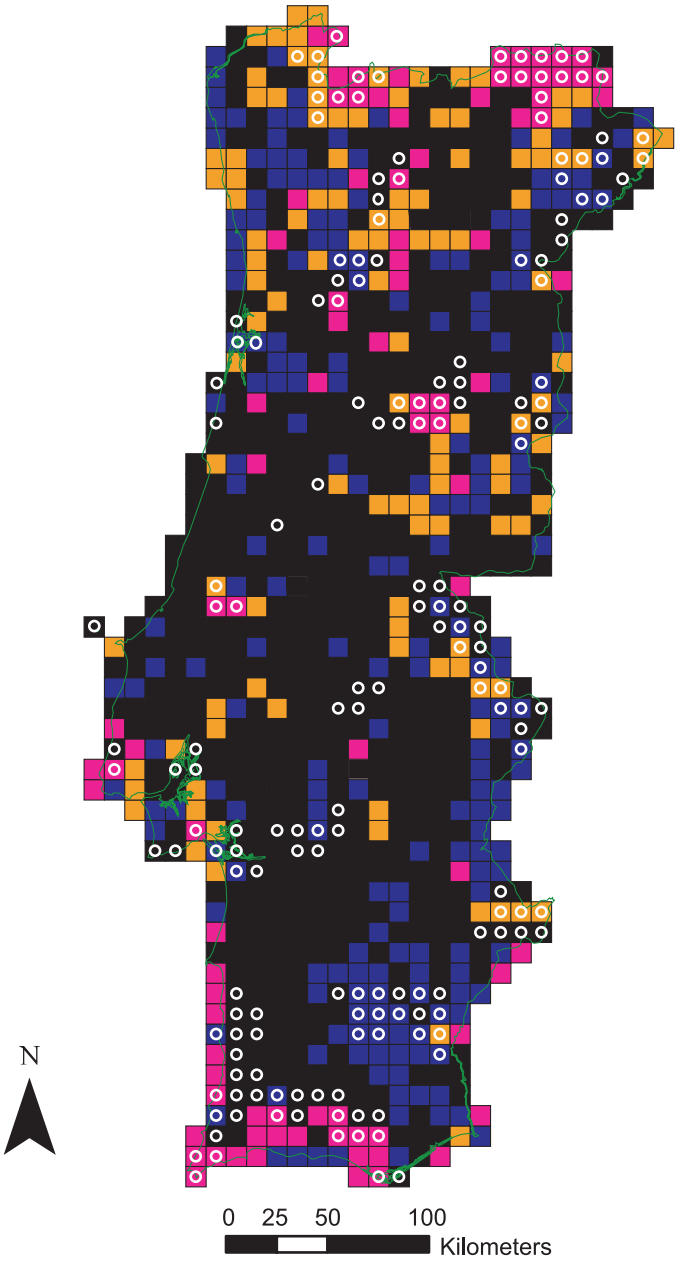


Figure 8.3. Biodiversity Irreplaceability Values in Portugal per 10x10 Kilometer Cell. Biodiversity irreplaceability is a measure of conservation options lost if the site were to be converted or further degraded (Pressey et al. 1993). The irreplaceability value is not an indicator of biodiversity condition, but can be useful in prioritizing areas for conservation. Cell colors indicate decreasing levels of biodiversity irreplaceability in the following order: red, yellow, blue, and black. White circles denote cells belonging to the Natura 2000 network of protected areas.

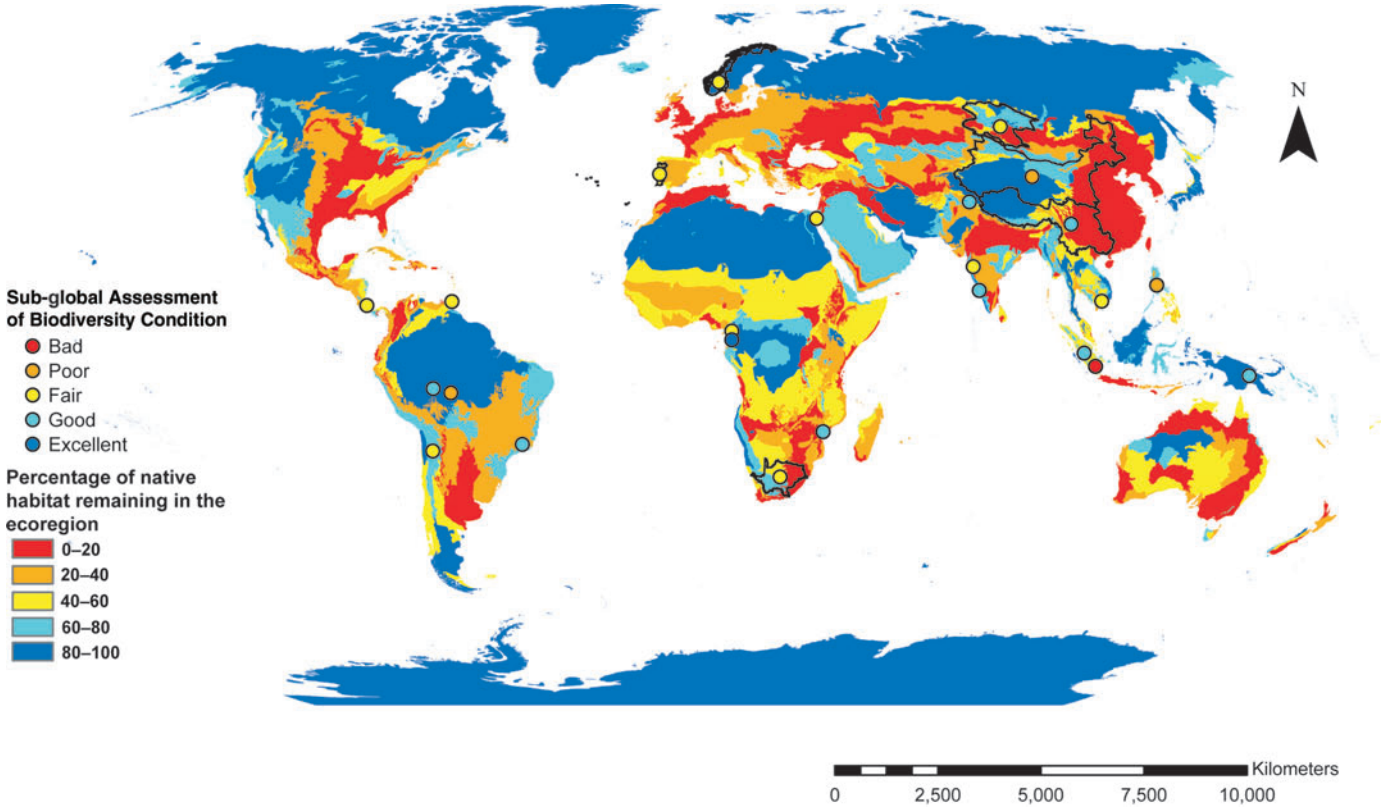


Figure 8.4. Comparison between the Sub-global Assessments of Biodiversity Condition and the Amount of Native Habitat Remaining in the Ecoregions of the World. The percentage of land converted to human-dominated uses (i.e., cropland and pasture) for each ecoregion was calculated with data from the MA Scenarios Working Group, using the land-cover map for the *Global Orchestration* Scenario in the year 2000 (Olson 2001). Sub-global assessments that assess large areas have the boundaries plotted in black (note that the Western China assessment area is divided into two sub-regions).

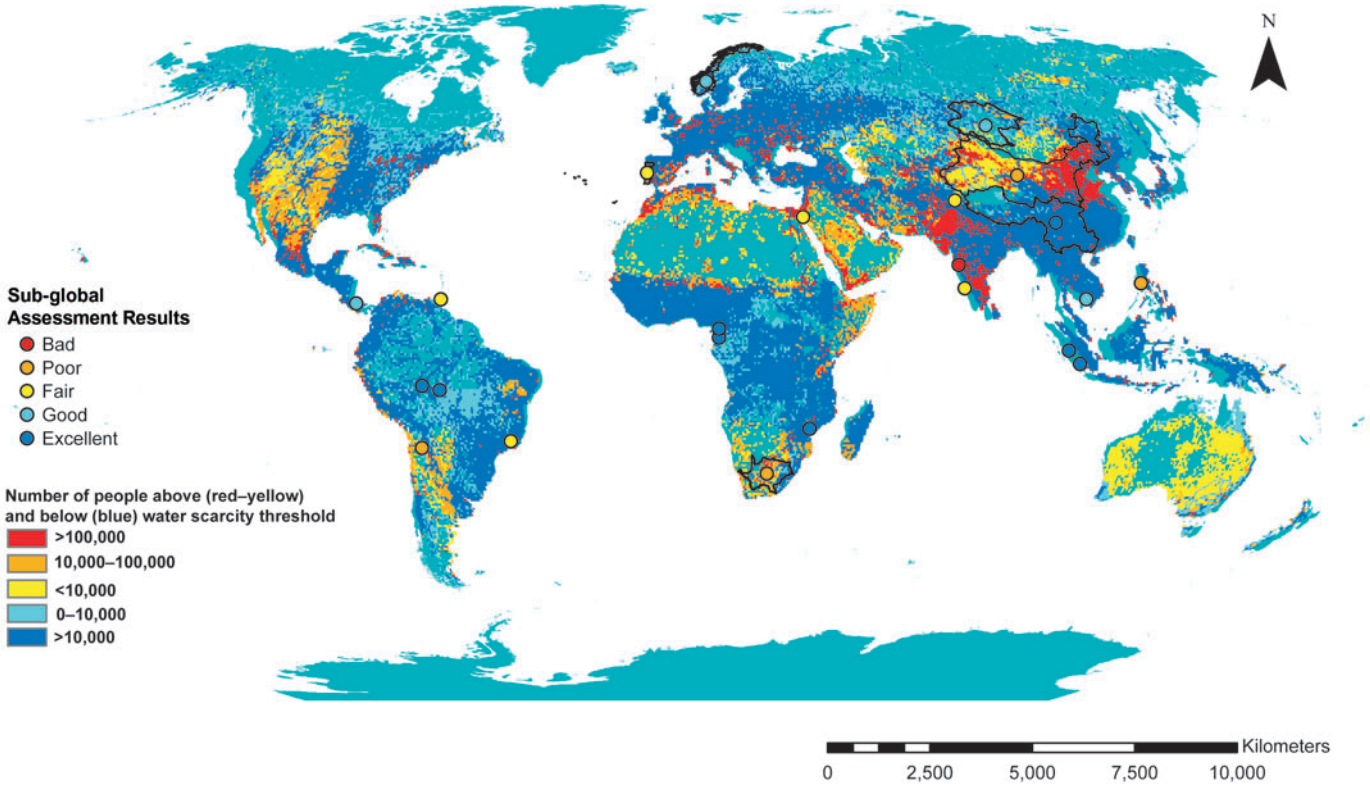


Figure 8.5. Comparison between Freshwater Condition in the Sub-global Assessments and the Global Distribution of Human Population in 1995 Relative to a Threshold of Severe Water Scarcity. This map shows the distribution of the human population which has severe water limitations (i.e., which is above the water scarcity threshold). The threshold corresponds to a ratio of 40% of water use or withdrawal to discharge (Vörösmarty et al. 2000). Boundaries of sub-global assessments that assess large areas are plotted in black.

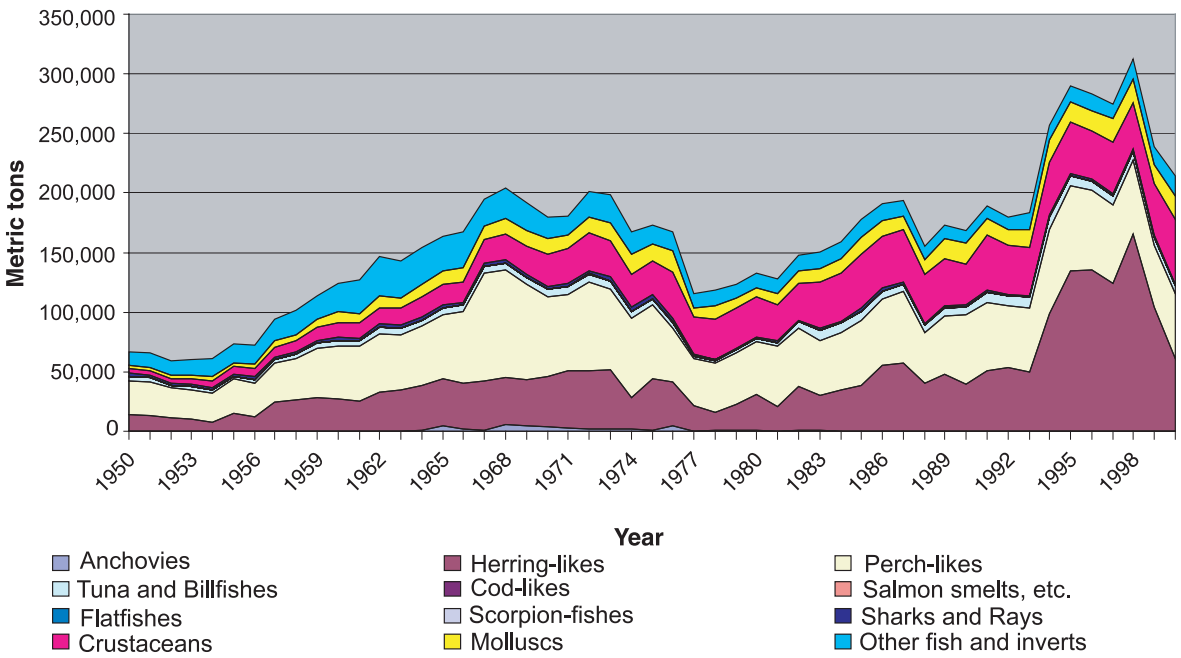


Figure 8.6. Marine Animal Catches by Animal Type in the Caribbean Sea

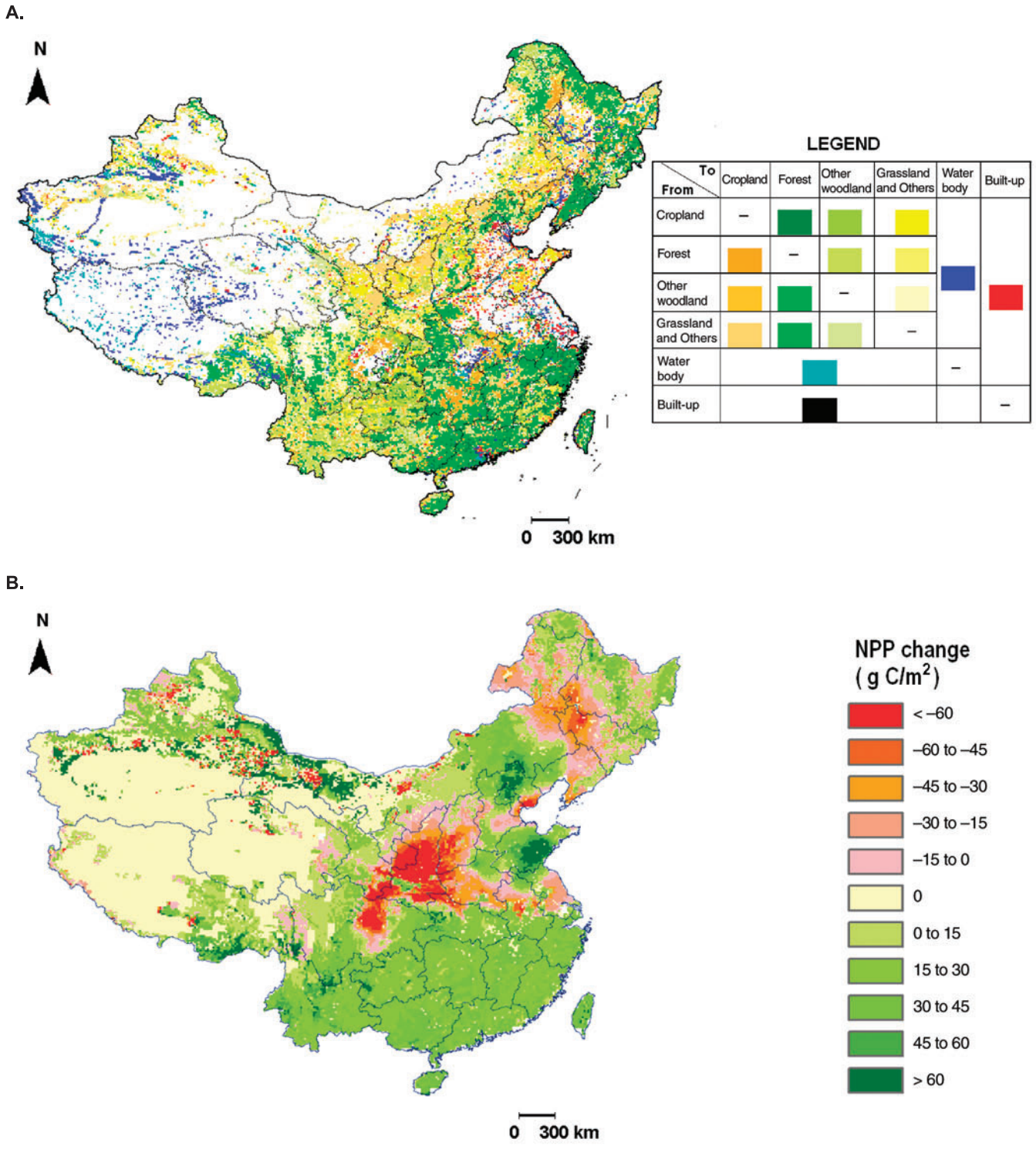
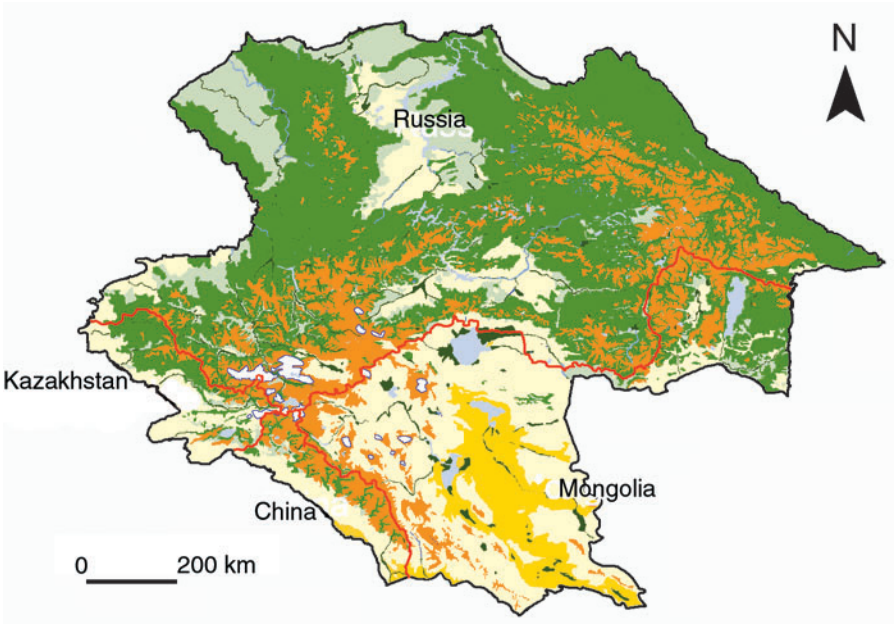
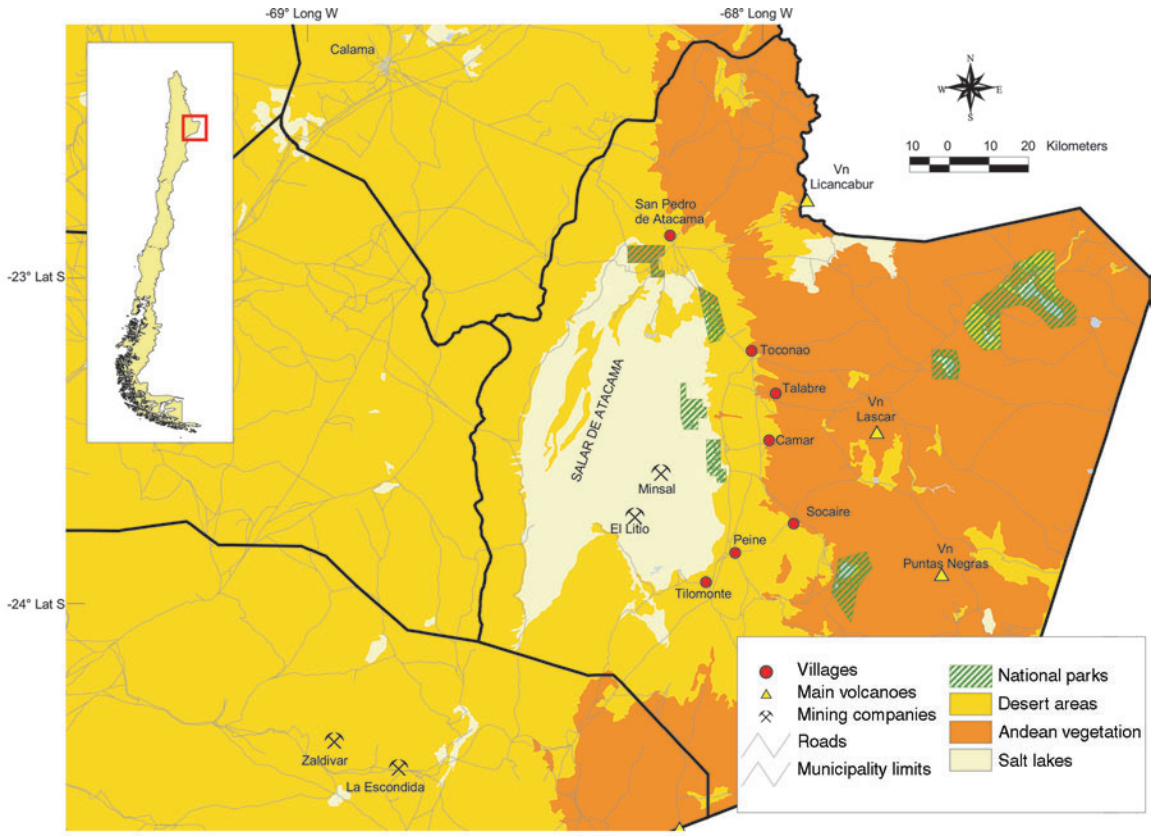


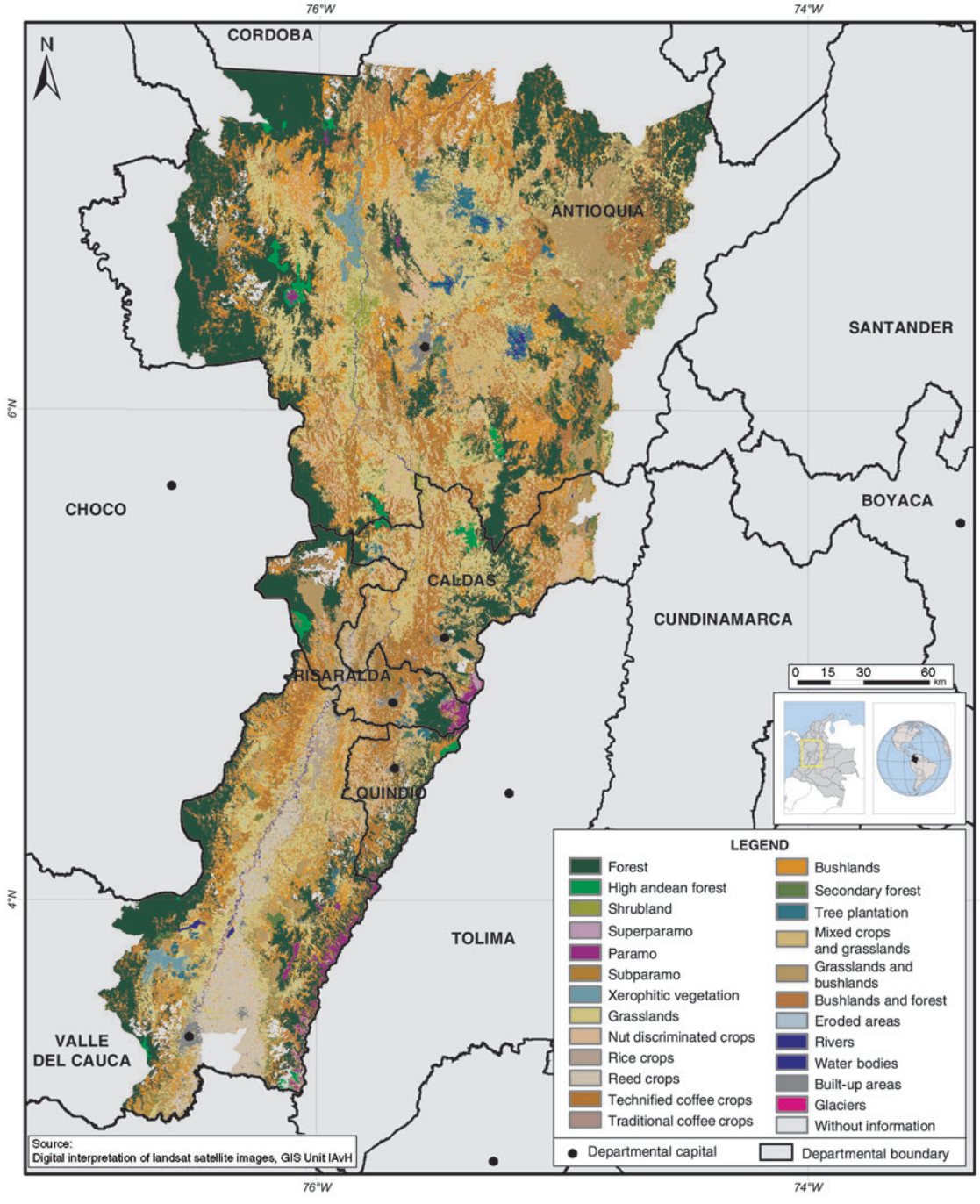
Figure for Box 8.8. Land Use Change from 1981 to 2000 (A) and Its Impact on Net Primary Productivity of Ecosystems (B).



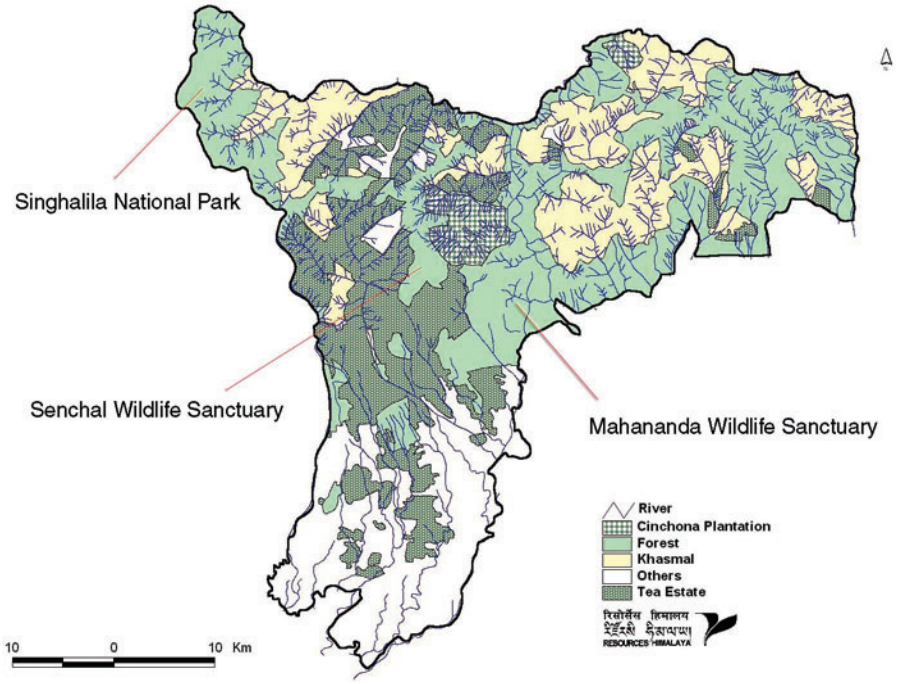
Altai-Sayan Ecoregion



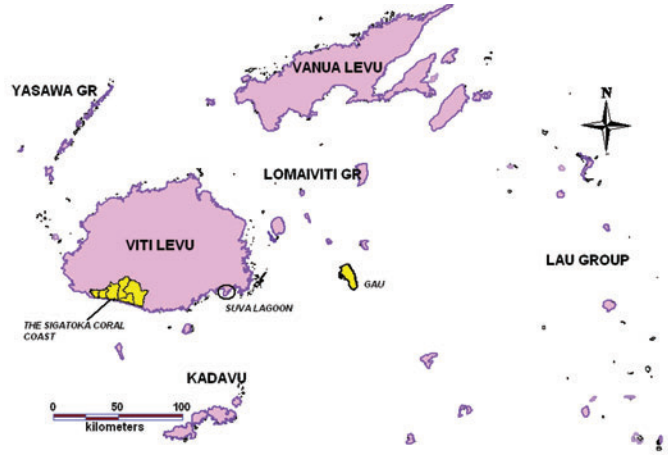
Study Area of the San Pedro de Atacama, Chile MA Sub-global Assessment



Ecological Function Assessment, Colombian Andean Coffee Growing Region

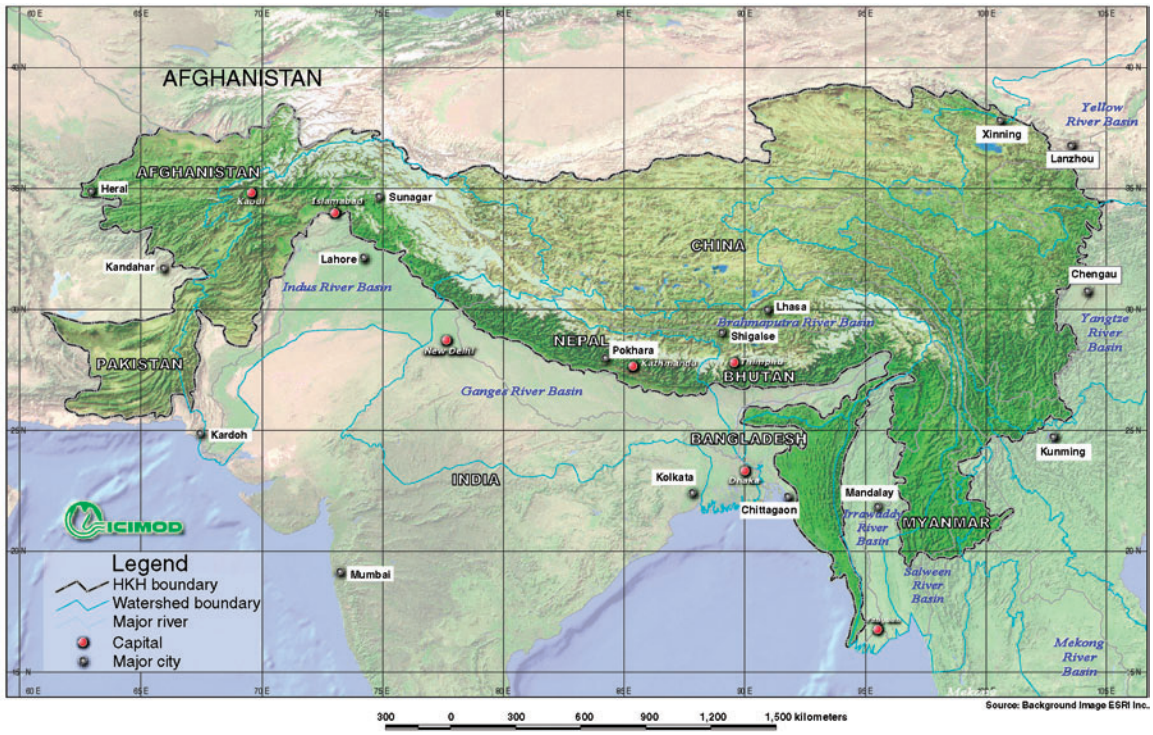


Eastern Himalayas Assessment

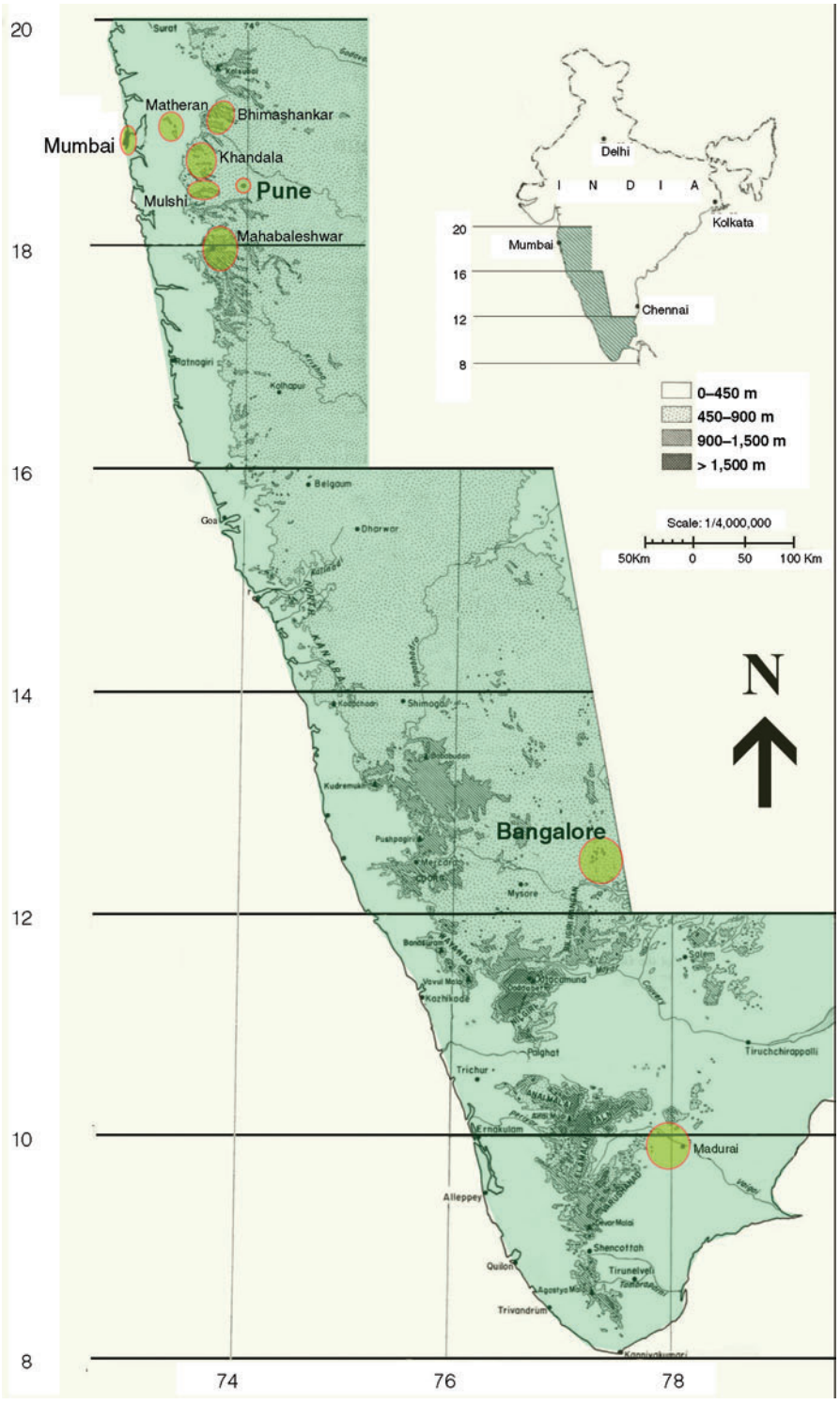


Fijian Assessment

Map of Caribbean Sea with Exclusive Economic Zones of Surrounding Countries (The Nature Conservancy)

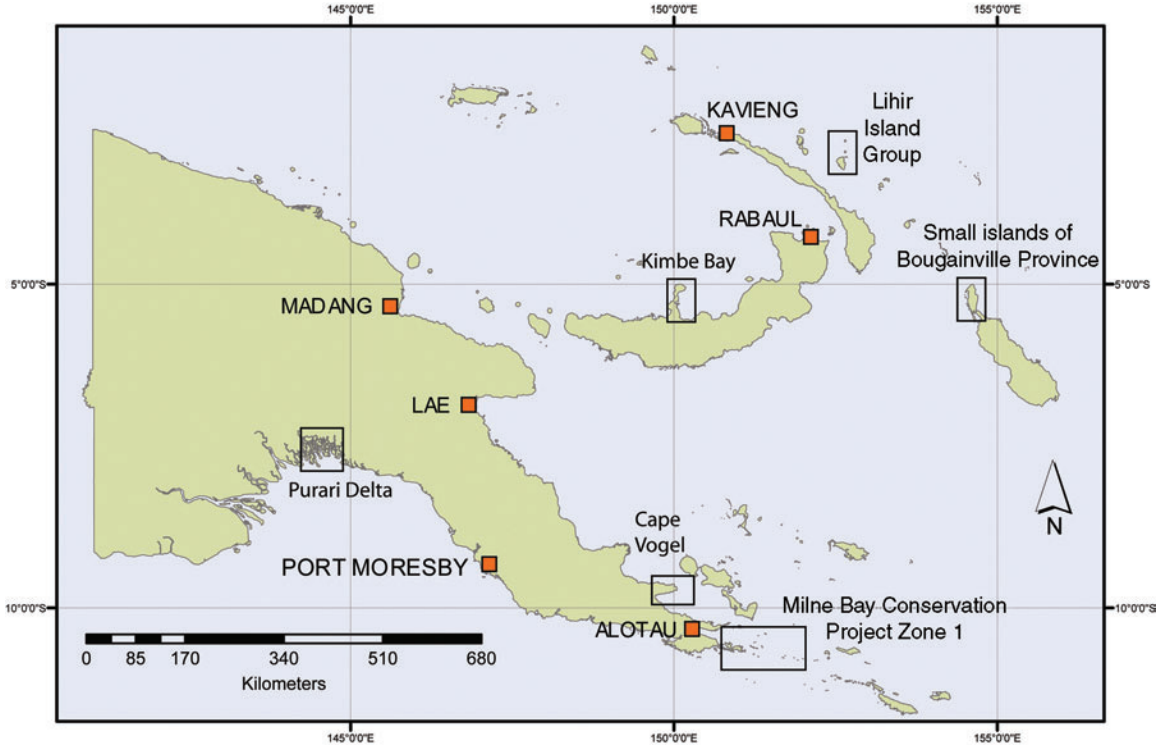


Hindu-Kush Himalayas

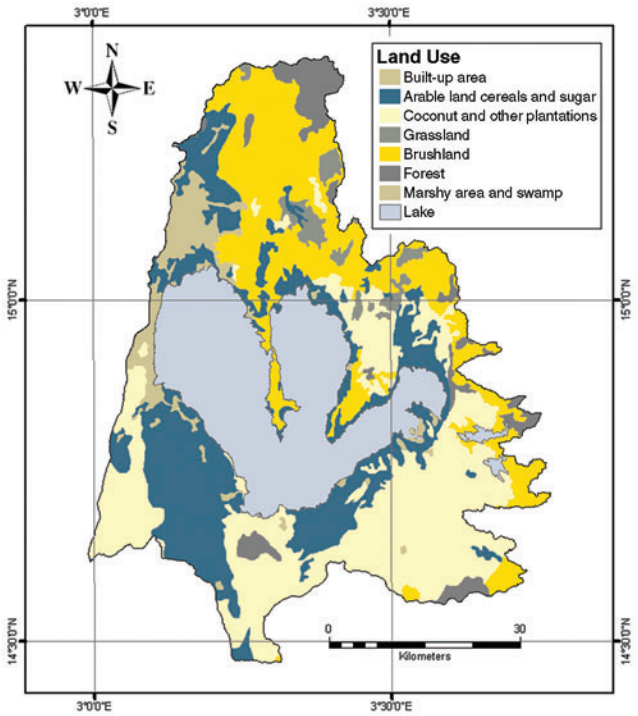


Indian Urban Resource Millennium Assessment

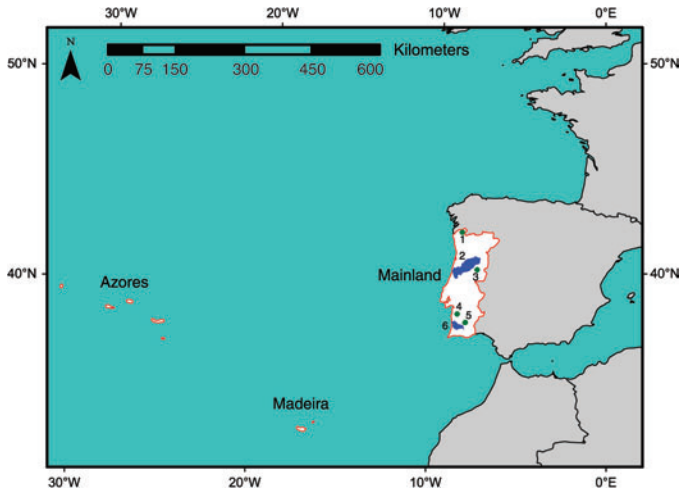
Glomma and Lägen River Basins



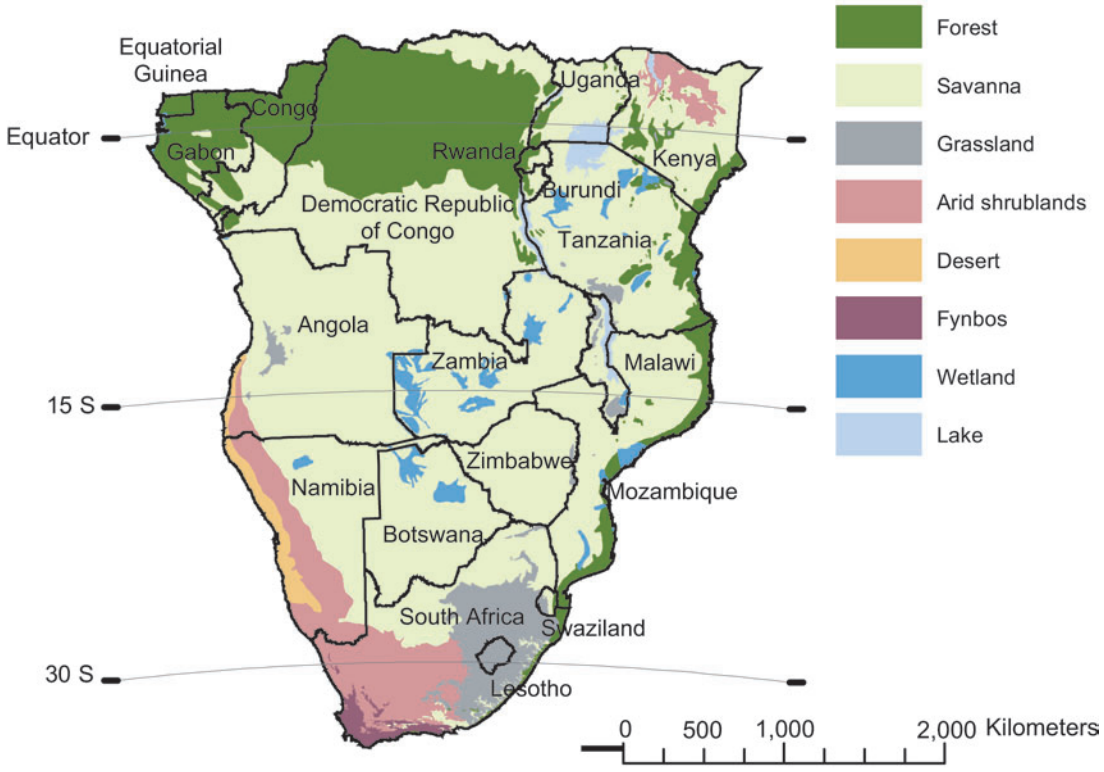
Papua New Guinea Coastal, Small Island, and Coral Reef Ecosystems



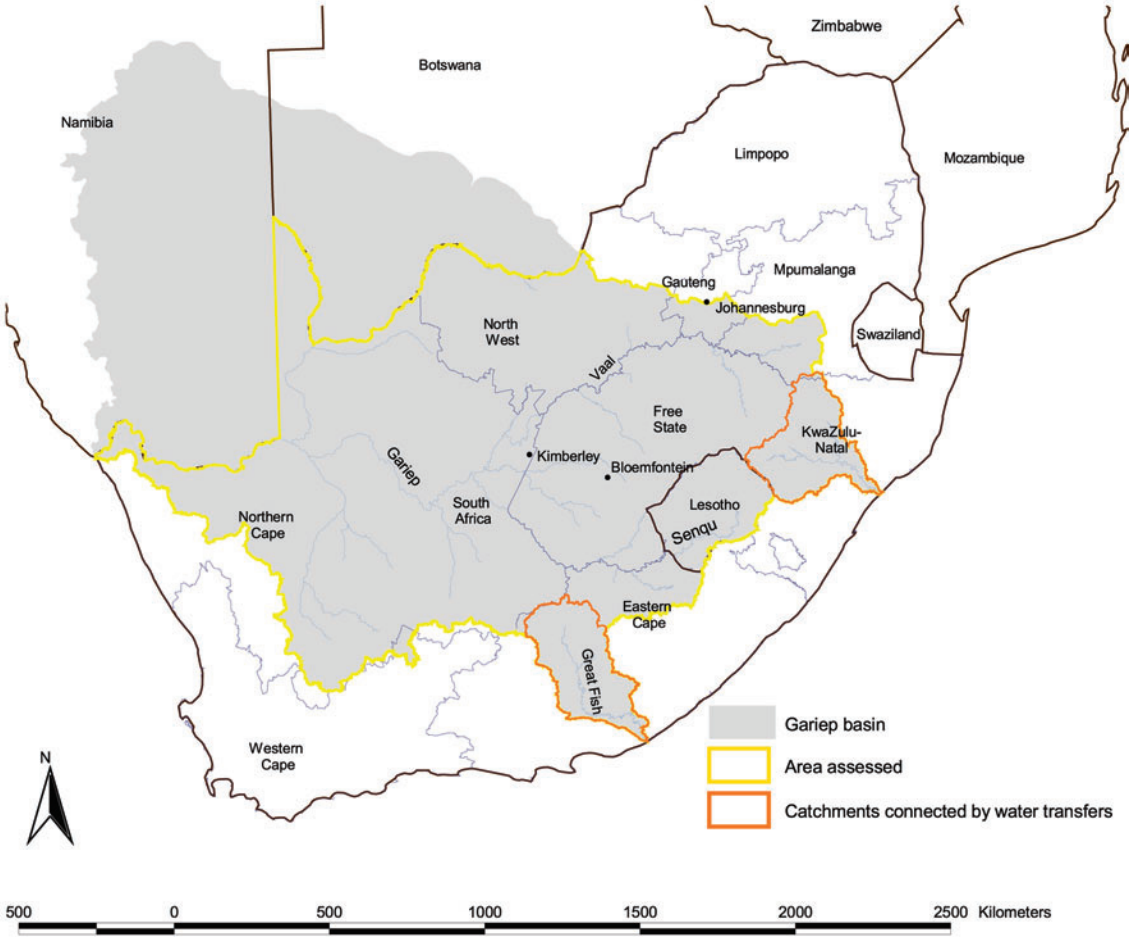
Laguna Lake Basin, Philippines



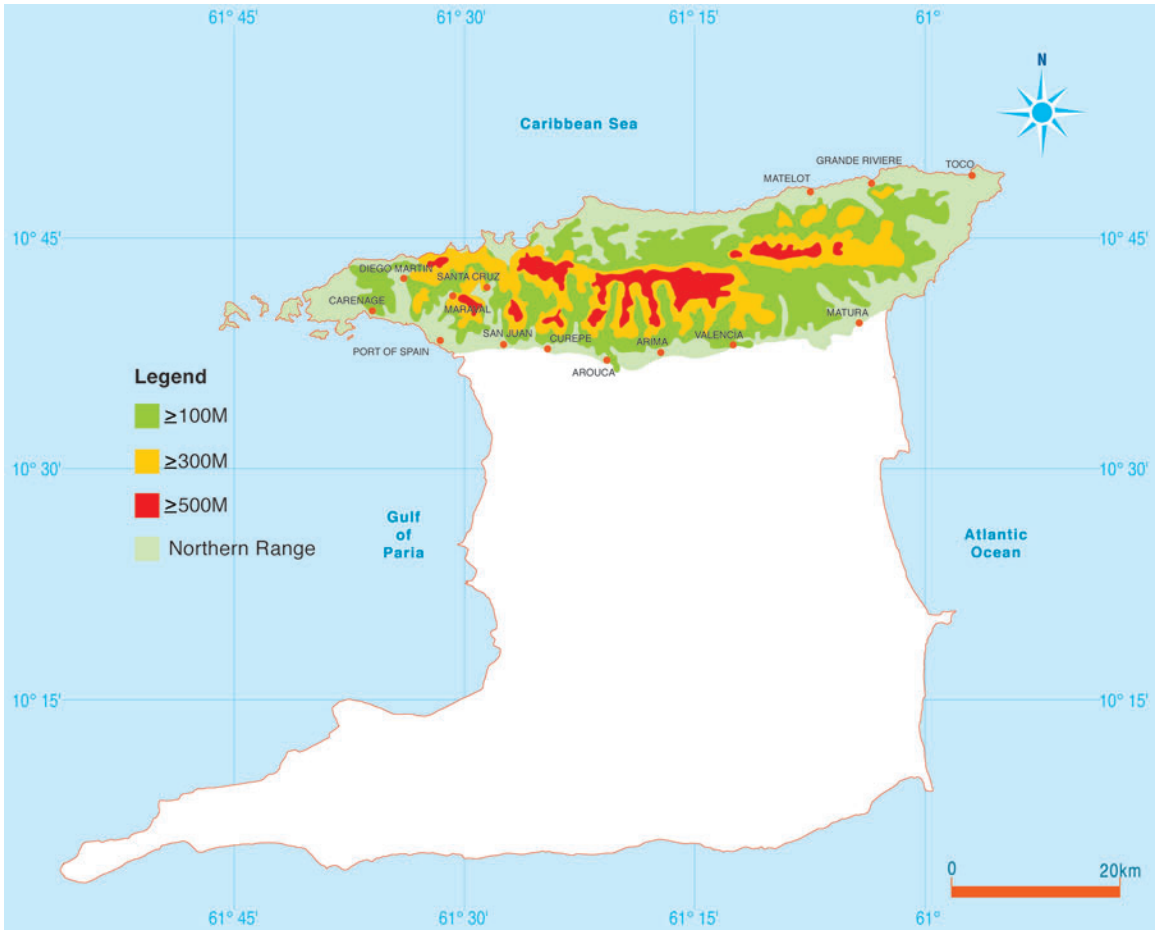
Portugal



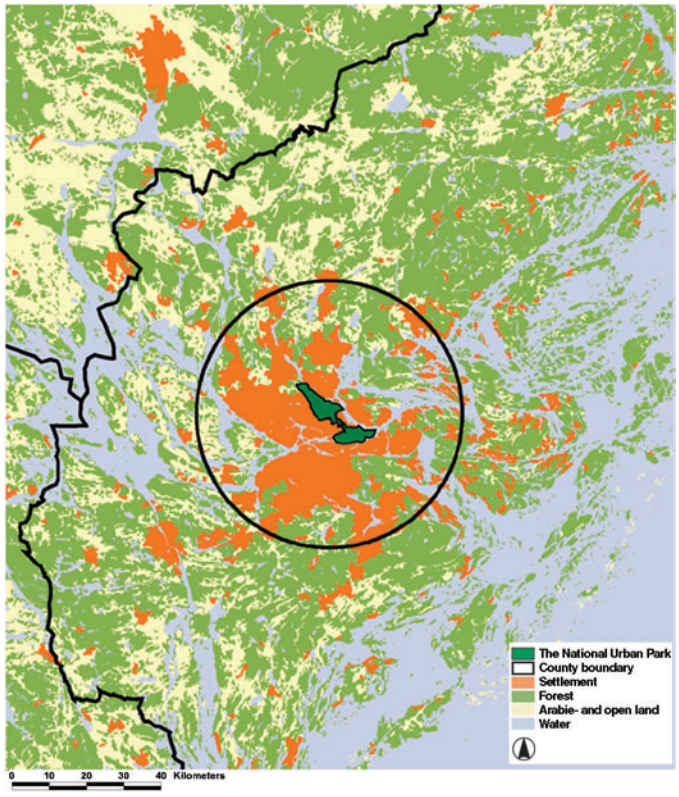
Southern African Regional Assessment. This covered 19 countries in mainland Africa south of the equator, and eight major biome types. (Scholes and Biggs 2004)



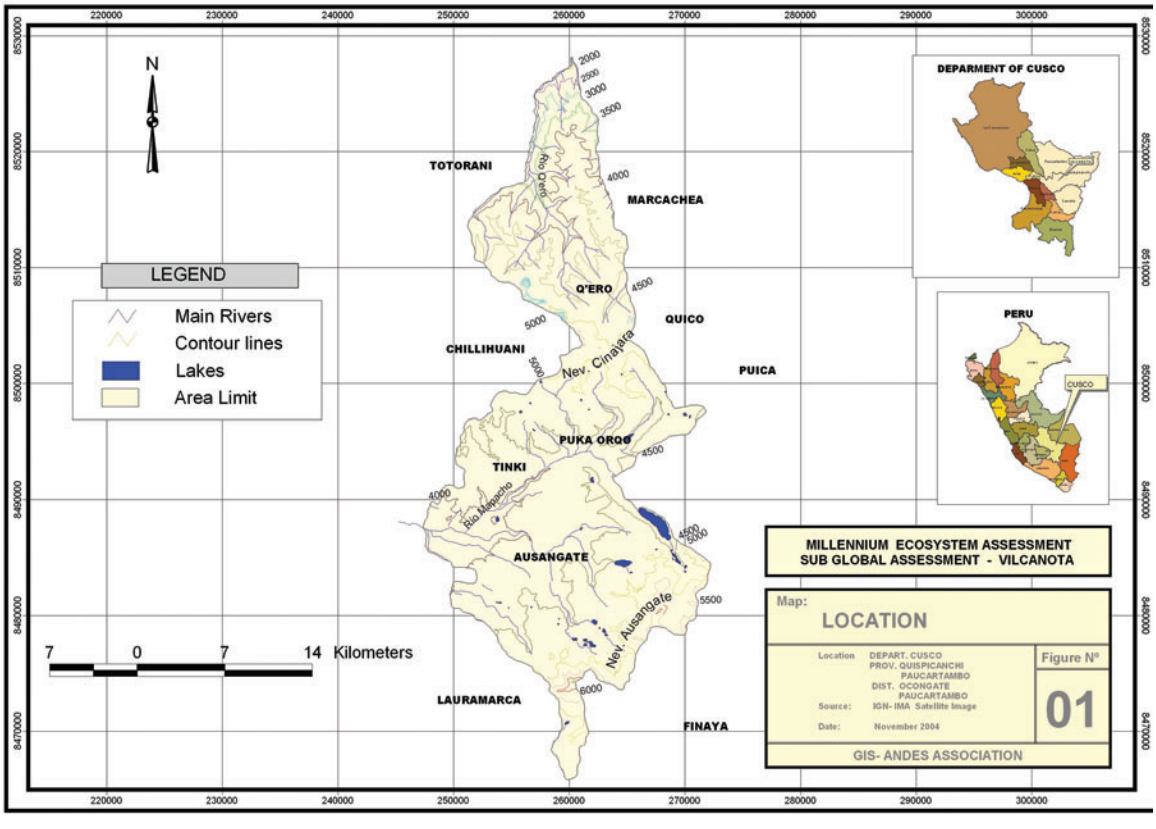
Location of the Gariep Basin, International Boundaries, South African Provincial Boundaries, Major Rivers, and Major Cities. Note that the actual Gariep basin extends beyond the area assessed. (Bohensky et al. 2004)



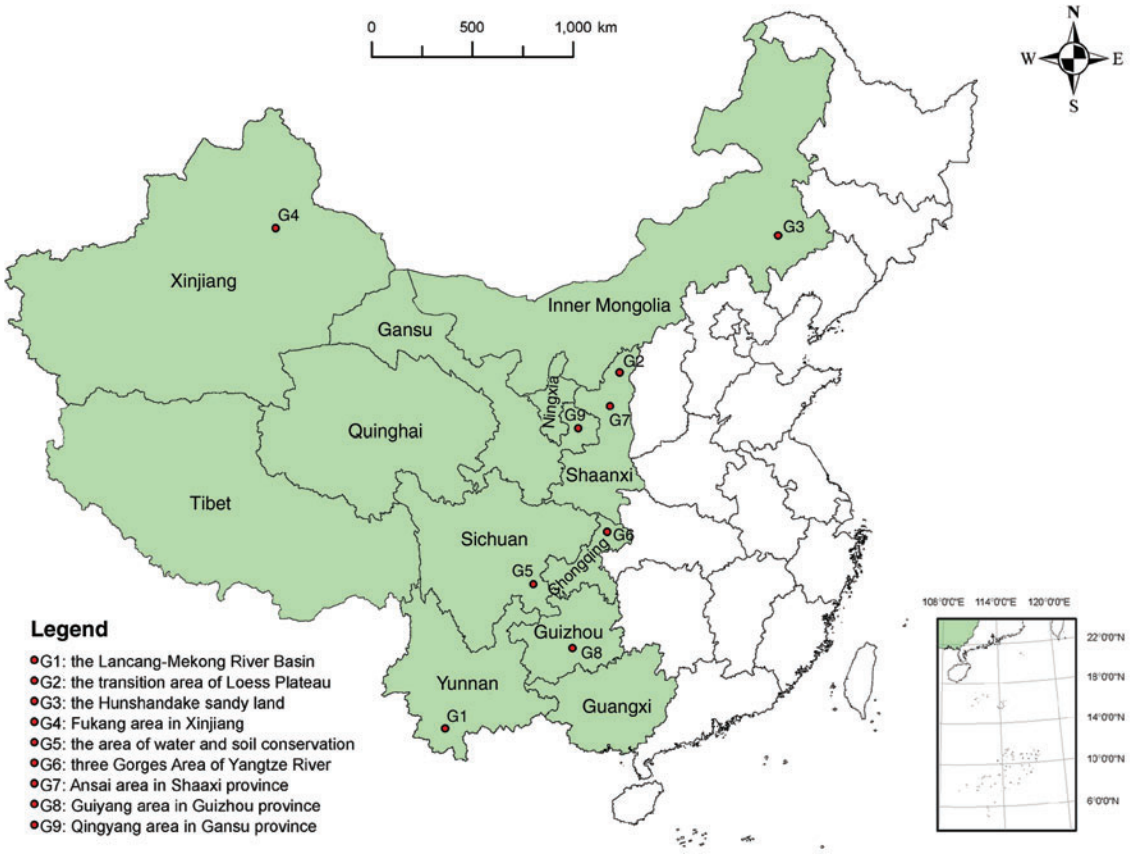
Map of Trinidad, Highlighting Topography and Major Towns of the Northern Range (Kenny 2000)



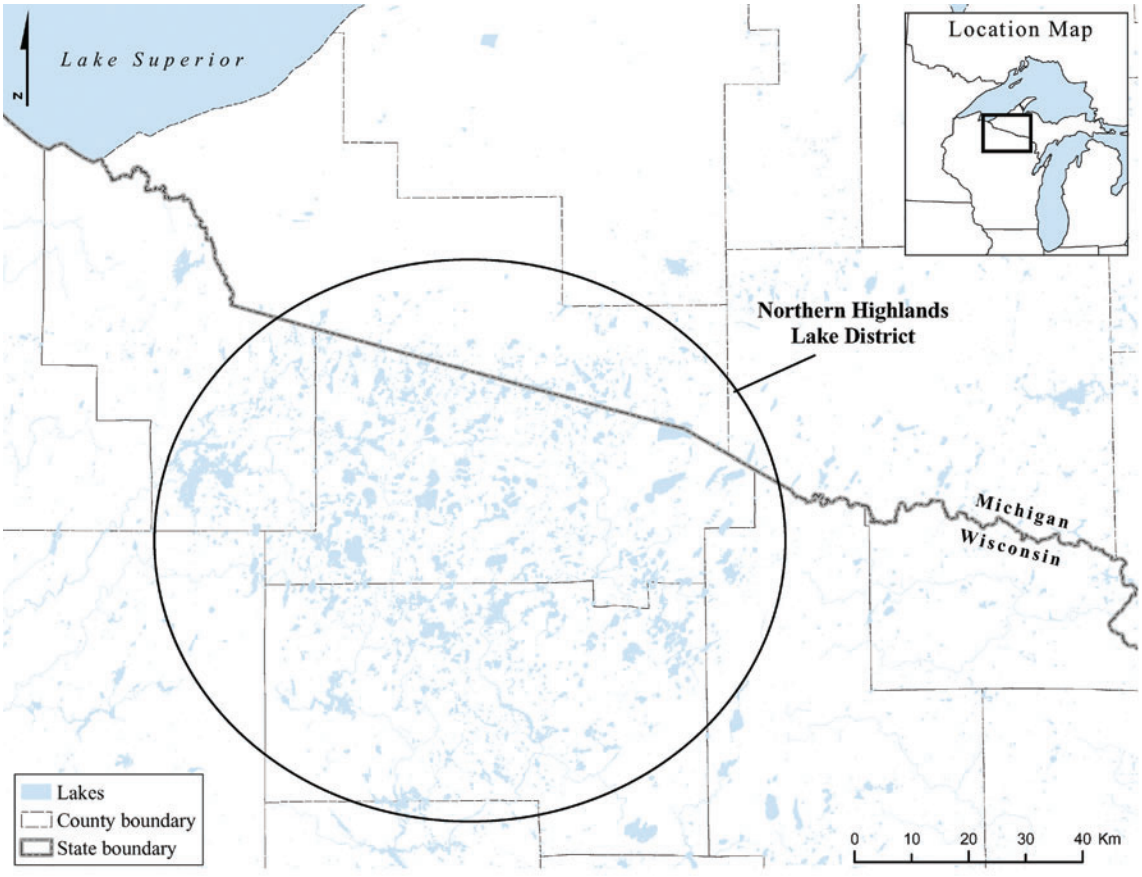
The Stockholm Urban Assessment. This assessment is located within a circle with a radius of 20 km surrounding the most central parts of the city. The National Urban Park is located in the center of this circle.



Vilcanota, Peru



The Western Region of China. The red points represent typical areas at local scale.



Northern Highlands Lake District, Wisconsin

Appendix B

Brief Summaries of the Sub-global Assessments

Alaska

Fire-mediated changes in the Alaskan Boreal Forest: Interactions of changing climate and human activities

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Paul Baer (resource economist), Stanford University
Orville Huntington, resident of Huslia; Vice-Chair, Alaska Native Science Commission
La'ona DeWilde, resident of Huslia

Location: Yukon River drainage of interior Alaska and western Canada (63.5–68°N; 130–160°W).

Time period:
Year range for assessment: 1800–present (detailed analysis since 1950)
Year range for scenarios: 2000–2100 (detailed projections through 2050)
Project time frame: Phase 1: September 2007; Phase II: September 2010

Project summary:
Recent economic and climatic changes in interior Alaska have interacted to reduce the well-being of rural residents and reduce the resilience of the region to projected future changes. The goal of this assessment is to document the changing role of fire, particularly as affected by human activities, on the Boreal system and its human residents and to explore alternative scenarios of future changes that might enhance or further reduce human well-being. Our study design is spatially hierarchical: the boreal forest of western North America, which contains two countries (Yukon Territory in Canada; Alaska in the United States), within which we study smaller regions centered on two communities in each country. Our study also has a temporal hierarchy of long-term trends (1800–2100), within which we study most intensively the period 1950–2050, where we have greatest confidence in past records and future projections. We focus primarily on two bundles of ecosystem services that are strongly affected by changes in climate and fire regime and on a set of management policies that alter the relationships among fire, ecosystem services, and human well-being.

Fire and climate warming alter climate regulation at large spatial scales by changing vegetation composition, energy exchange with the atmosphere, and carbon balance. We study how these ecological changes either amplify or buffer the rate of climatic warming. These climate feedbacks also influence the consequences of state/territory and national policies of carbon sequestration and fire suppression. Human effects on, and responses to, fire at this scale are currently small. Ecosystem modeling (the Terrestrial Ecosystem Model or TEM) and policy analysis are the primary tools used to study these large-scale processes.

Fire and climatic warming modify provisioning and cultural services such as subsistence foods (for example, game, berries, firewood), economic opportunities and risks (for example, wages, property risk), and cultural ties to the land (as reflected in altered subsistence activities, rural-urban migration, and forest harvest). We document changes in subsistence foods based on ecological observations and interviews with subsistence users. We then use a landscape model of climate-fire-vegetation interactions (the Alaska Frame Based Ecosystem Code or ALFRESCO) to explore how future changes in climate and fire policy might alter fire regime and ecosystem services. The landscape pattern of these changes determines the consequences for use by local communities. We use records of fires, employment, and community income to assess the positive and negative economic effects of fire on communities. We assess conditions and trends through stand-age reconstructions, maps of fires since 1950, and interviews with elders. We explore scenarios through landscape modeling.

Policy and management influence the ways in which climate and fire affect ecosystem services through policy effects on fire pattern and extent and on the wages available to support subsistence. Fire policies respond to both national and local pressures for change. Game management policies influence both the availability and harvest of ecosystem goods by local communities.

References:
Web page: http://www.hfi.uaf.edu/
System overview: **Chapin,** F.S., III, et al., 2003: Planning for resilience: Modeling change in human-fire interactions in the Alaskan boreal forest. *Frontiers in Ecology and the Environment* 1, 255–261.

Funding: U.S. National Science Foundation (September 2003–2006; $1.14 million).

Altai-Sayan Ecoregion

(See color version of locator map in Appendix A.)

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Time period: 2003–ongoing.

Intended audience: local, national and regional decision-makers.

Issues addressed:

Biodiversity. The high value of ecosystems and biodiversity of the Altai-Sayan ecoregion is fundamental in considering it one of the key Global 200 Ecoregions identified by the WWF and recognized by the United Nations and World Bank (3,726 species of vascular plants are registered in the region including 700 threatened or rare species, 317 of which are endemic; fauna consists of 680 species, 6% of which are endemic). The ecoregion is the northern range of the natural habitat of the snow leopard (*Uncia uncia*) and Altai mountain sheep argali (*Ovis ammon ammon*). Poverty, widespread unemployment, and a lack of alternative economic activities are serious socioeconomic drivers that could negatively impact the biodiversity of the Altai-Sayan. Exploitation and strain on natural resources are increasing rapidly in the ecoregion. Protection of biodiversity in the region also depends on the ability of the local communities to maintain traditional land use patterns and practices.

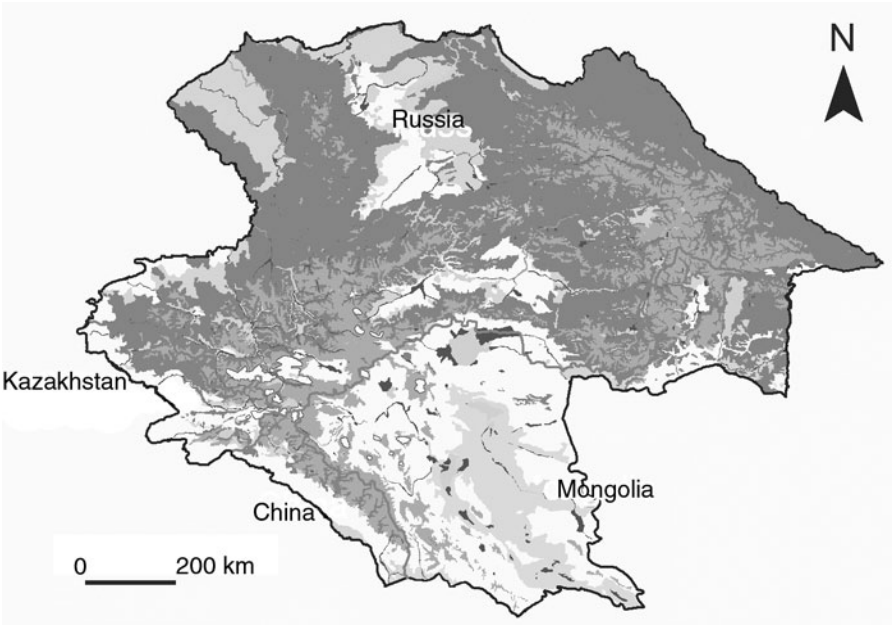
Natural forests. The present-day condition of the main provisioning goods—timber and firewood—of forest ecosystems in the Altai-Sayan ecoregion overall is estimated to be good. However, the condition is reduced to fair or even poor in some localities that are under human pressure or where unsustainable use, including illegal logging, is practiced. In the foreseeable future, forest ecosystems of the region will continue to provide people with the resources they demand, while also continuing to provide other supporting and regulating services. However, this will be sustainable in the long-term only if the state controls the use of forest services at current levels.

The existing data and modeling outputs are not sufficient to address questions about the impact of climate change on forest ecosystems and related consequences for human well-being. New studies on the impact of climate change on forest ecosystems of the Altai-Sayan ecoregion are urgently required. In the recent decades, the leading drivers of change in the region's forest ecosystems have been commercial logging and fire. Fire impact will increase in the future, owing to human activity, economic change, climate change, and pests.

Grazing lands of Western Mongolia. Overgrazing and overharvesting of biological resources (timber, wildlife) in western Mongolia is a result of the impoverishment of the country's population, who have few livelihood options and who depend almost entirely on natural resources. Mongolia's transition to a market economy caused some adverse effects on the state of the environment and grazing ecosystems. One of the effects related to changes in grazing lands was caused by the cessation of seasonal grazing, which has been practiced by Mongolian nomads for millennia. Seasonal herding led to a distributed impact on all grazing lands of the region. The abandonment of traditional herding practices was accompanied by an increase of livestock concentrated close to settlements and water sources. This caused overgrazing and even complete degradation of grazing lands in some places.

Based on the assessment of the current state and trends of grazing ecosystems, it is possible to define priorities for social responses to the current situation and future developments, including elements of a social strategy related to the use of natural resources and sustainable resource management.

Regional waters and climate change. Pronounced climate warming has been observed in the region in recent decades, and has resulted in the Altai glaciers receding and shrinking. In the case of the Katun River,



Altai-Sayan Ecoregion

which drains the northern slope of the Altai high mountains, there was no increasing trend in the river's runoff from 1950 to 2000. However, there was a noticeable trend of decreasing differences between seasonal runoff in the high and low mountains of the Katun basin. This is explained by the different responses of the rivers, with runoff forming in different elevation zones according to seasonal changes in precipitation. Currently the population and the economy have a much more significant impact on the water quality of rivers and lakes than does climate change. An increase in population and growth of the economy will likely cause rapid changes in the condition of regional waters, especially through surface water pollution.

Environmental consciousness of rural populations. The rural population in Altai-Sayan is slowly moving from the utilitarian and negative environmental paradigm of "extraction and utilization" towards new ethical principles regarding the environment. People have become aware of the need for environment protection and conservation. This is reflected in public behavior (environmental protests, establishment of new environment NGOs), although it is still rare. It has also been observed in new economic behavior and in the establishment of environmentally friendly businesses, related to the sustainable use and regeneration of local resources. This has taken place without the assistance and initiative of central authorities or the mass media.

Arafura and Timor Seas

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Location: The Arafura and Timor seas are contiguous, semi-enclosed seas bordered by Indonesia and Timor-Leste to the north, Papua New Guinea to the west, and Australia to the south. The Pacific flows into the Arafura and Timor seas through the Torres Strait.

Lead institution: The Arafura and Timor Seas Forum (ATSEF) is a non-binding forum for collaboration between Indonesia, Timor-Leste, Papua New Guinea, and Australia for the sustainable use of the living resources of the Arafura and Timor seas.

Focal issues: The sub-global assessment focuses on four sets of institutional, biophysical, and systems dynamics priorities:

- institutional: impact of illegal, unreported, and unregulated (IUU) fishing in the Arafura and Timor Seas;
- institutional: assessment of sustainable and/or alternative livelihoods for coastal and indigenous communities;
- biophysical: assessment of fish stocks, marine habitats, and coastal and marine biodiversity; and
- systems dynamics of the seas.

Ecosystem services assessed: Fish stocks, marine habitats, coastal and marine biodiversity, wetlands, and carbon sequestration.

Key features of assessment area: These semi-enclosed seas are the global maximum for marine biodiversity. The seas have a carbon sequestration capacity that markedly exceeds other marine regions, despite containing the richest known hydrocarbon deposits. They are among the few seas where stocks depletion has been minimal, though that status is deteriorating rapidly. The near coast of much of the region consists of wetlands/floodplains that are critical to migratory bird species. Despite this abundance, 50% of the population of the coastal communities and the littoral states live below the absolute poverty line.

Argentine Pampas
The provision of ecosystem services and human well-being in the Pampas of Argentina

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Time period: the assessment of condition and trends extends from 1880 to 2000, but detailed information is provided only for the period 1960–2000. Scenarios are projected to the year 2025.

Relevant findings: The assessment looks at four increasing geographical scales (farm, major agroecosystems, the whole Pampas, and the Del Plata basin) and time periods (from one year to four decades). Some relevant findings in relation to the supply of ecosystem services and their impact on human well-being in the Pampas are the following:

Food production. Since the beginning of colonization (1879), the Pampas of Argentina have shown their ecological potential for food production at a commercial scale. Crop and beef productivity have been growing steadily at increasing rates, and this has resulted in increased surpluses to fulfill domestic and export needs. Today, the dynamics of Argentina's economy strongly depend on the Pampas' provisioning and underlying ecosystem services. Current production is still far from the biophysical potential of ecosystems, and there is enough room to increase productivity through (1) the conversion of natural and cultivated grazing lands into croplands, and (2) increased use of external inputs. We expect that the profile of the Argentine Pampas as an international food supplier will be confirmed in coming decades and the Pampas will have an increasing economic impact at the regional, the national, and the Del Plata basin scales.

Soil erosion control and carbon sequestration capacity. Since the end of the nineteenth century, land use conversion for increasing food production has deteriorated the capacity of ecosystems to control soil erosion and sequester atmospheric carbon in soil and vegetation. Considering that these ecosystem services are coupled, they have been affected by similar changing factors. The persistent conversion of natural grasslands into cultivated lands, the extensive use of fire for managing rangelands and grasslands, the introduction of ruminant grazing cattle, and the spreading of non-conservative tillage operations for more than 80 years, have triggered frequent soil erosion episodes and transformed a carbon-sequestering region into a carbon-emitting one. Soil erosion has a broader scale, off-site impact (water sedimentation) on the Del Plata basin mouth. Carbon emission from the Pampas has, on the other hand, impact on atmospheric warming at a global scale but which has not been fully assessed. In recent times, declines in both these services have stopped and even been slightly reversed due to the extensive application of no-till practices. These practices are driving both a re-accumulation of soil organic carbon and a drastic reduction in fossil fuel consumption.

Freshwater provision. In quantitative terms, freshwater provision is not a limiting factor for human well-being in the Pampas. However, the increasing utilization of chemical inputs (especially pesticides and fertilizers) due to the expansion of the cropping area is probably affecting water quality in various areas of the region. Our regional scale studies using models tend to demonstrate that the risk of water contamination is increasing in areas where continuous cropping predominates. These estimations are confirmed by non-point field measurements over recently converted lands. Because of multiple surface and groundwater connections, contamination at the farm scale spreads to broader scales.

Habitat provision. All over the region, the expansion of cultivation is causing rapid simplification of the rural landscape, especially in continuously cropped lands. Although the systematic assessment of biodiversity is still uncommon in the Pampas, the fragmentation of landscapes, the utilization of conventional tillage, and the application of pesticides have all been consistent causes of decline in habitat provisioning. Thus we can presume that wildlife biodiversity is persistently declining over the whole region, but particularly in the more intensively impacted ecosystems.

Nutrient cycling. The replacement of rangelands and cultivated grasslands by croplands is deeply modifying the nutrient cycling in ecosystems. Our studies have revealed an increasing weakness of organic compartments in nitrogen (N) and phosphorus (P) cycles. The retention of N and P in strong organic compartments has maintained a robust functioning of nutrient cycles when rangelands and legume-based cultivated grasslands have predominated over croplands. The expansion of croplands during the last 20 years has caused rapid depletion of the soil nutrient endowment and a growing use of inorganic fertilizers (especially N) to compensate for this. Increased leakage of nutrients and the risk of water contamination were unavoidable results. On-site actions affecting nutrient cycles have off-site effects at wider scales. Thus the disruption of nutrient cycles not only affects the on-site maintenance of soil fertility, but also puts at risk the off-site provisioning of good-quality fresh water.

References:

Bernardos, J.N., E.F. Viglizzo, V. Jouvet, F.A. Lértora, A.J. Pordomingo, and F.D. Cid, 2001: The use of EPIC model to study the agroecological change during 93 years of farming transformation in the Argentine pampas. *Agricultural Systems* 69/3, 215–234.

Viglizzo, E.F., A.J. Pordomingo, M.G. Castro, and F.A. Lértora, 2003: Environmental assessment of agriculture at a regional scale in the Pampas of Argentina. *Environmental Monitoring and Assessment* 87, 169–195.

Funding: National Institute for Agricultural Technology (INTA) of Argentina.

San Pedro de Atacama, Chile
Human well-being and sustainable management of the Salar de Atacama ecosystem

(See color version of locator map in Appendix A.)

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Project coordinating institutions: RIDES, *Recursos e Investigación para el Desarrollo Sustentable*. RIDES is a research center—an NGO based in Santiago, Chile. Its mission is to develop applied research to contribute to public and private policies for sustainable development in Chile and in the South American region.

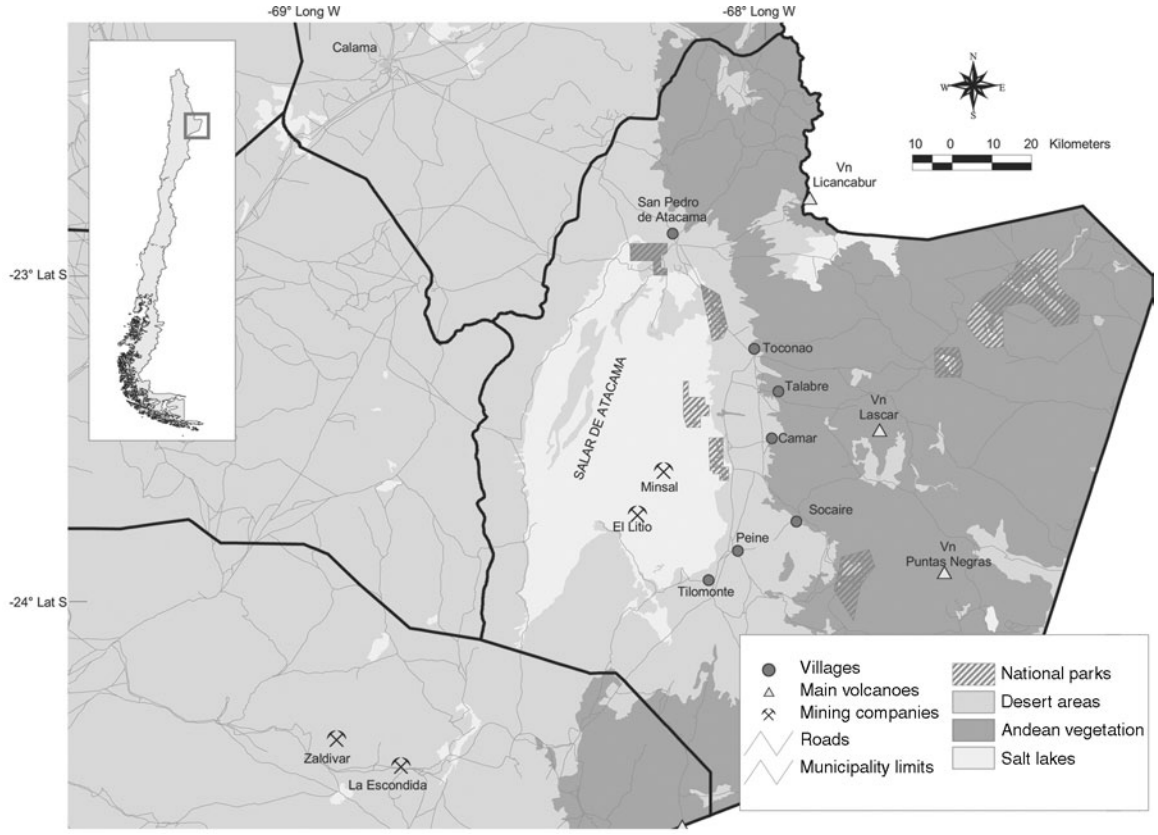
Project time frame:
Range for which the condition and trend assessment applies: last 10–15 years.
Range for which the scenario projections apply: 5–20 years.
Work time frame: June 2003–February 2005

Summary of important findings and methodologies used: The table summarizes the links between the ecosystem services studied in the project and human well-being.

References: RIDES Web site: www.rides.cl.

Funding: The project received $95,000 from the MA; approximately $4,000 from mining companies; approximately $7,000 from public sector agencies (final figure to be confirmed); and in in-kind cooperation from various agencies (private and public) on the order of $2,000.

Acknowledgments: The following institutions/programs have actively collaborated with the project: interdisciplinary studies on biodiversity program, *Programa Interdisciplinario de Estudios en Biodiversidad,* Universidad de Chile (www.biodiversidad.uchile.cl); Forestry Agency, CONAF (www.conaf.cl); indigenous people's development area, *Área de Desarrollo Indígena Atacama la Grande*; San Pedro de Atacama municipality; and two mining companies—Compañía Minera Zaldívar (www.cmz.cl) and Minera Escondida Limitada (www.mel.cl).



Study Area of the San Pedro de Atacama, Chile MA Sub-global Assessment

Ecosystem Service	Link to Human Well-being	Indicators
Water	A scarce resource fundamental for human life and ecosystem support. Economic activities such as mining, agriculture and tourism depend upon water availability. Water scarcity has generated conflicts between the main users. Water quality is another issue: high levels of arsenic are naturally present.	In Chile there is a water market, ruled by the Mining and Water Law. Indigenous communities and related public institutions do not have enough resources to buy water rights, compared to the mining companies. Distribution of water rights and requests (requests exceed available volume) **Potable Water.** Rights: 817 l/s (13%); Requests: 288 l/s **Irrigation.** Rights: 3,008 l/s (47%); Requests: 5,049 l/s **Mining.** Rights: 2,600 l/s (40%); Requests: 5,518 l/s **Brine exploitation.** No information yet. **Recreational.** 20 l/s (<1%) ; Requests: 0 l/s 68% of the population does not have access to treated water. Only in San Pedro is water potable. Mining improvements: MEL imposed itself the goal of recycling 38% of water consumed in operations; CMZ reduced its annual consumption of water by about 800 cubic meters between 1995 and 2002.
Tourism	Source of employment and income to local communities (indigenous and non-indigenous). For indigenous people, it is an opportunity to revalue their culture and landscape. Tourism, on the other hand, affects the traditional lifestyle of local communities and might contribute to pollution (waste, noise, etc.).	The two main sources of local employment are: construction (17.7%) and hotels and restaurants (15%). For the year 2000, tourism income in San Pedro de Atacama was about $5,381,000 Local population: 4,696 Visitors: around 3,800 monthly visitors in high season and 1,800 in low season.
Minerals	Source of employment and income to local communities (indigenous and non-indigenous). At the regional and national level it is a major source of revenues and a main contributor to GDP. Mining is the main water user and is also a source of waste and risks.	Mining is the third largest source of local employment (11.4%). Mining represents 4.8% of national GDP and 66.21% of regional GDP (1999). Mining consumes more than 65% of available water in the region.
Biodiversity	Supports the life cycle of basic elements (water, nutrients, etc.), providing elements and resources (like bogs(for animals (birds, llamas, foxes, etc.) and human life (seeds, wood fuel, vegetables, and fruits). Biodiversity is a constitutive element of the Atacameños' culture; expressions of this are, for example, the use of flamingo feathers in religious ceremonies and the use of herbs in traditional medicine.	Bogs represent 0.07% (1,697 ha) of the municipality's total area. Three species of flamingos: F. Chileno (*Phoenicopterus chilensis)*, F. Andino (*Phoenicoparrus andinus)*, F. de James (*Phoenicoparrus jamesi)*. The Salar is the world's largest nesting site of flamingos, and the only area in which the F. Andino is found. 3% (73,983 ha) of the whole area is protected by the state.
Agriculture and livestock	Historically, agriculture was a main economic (and also cultural) activity; it fostered the development of the Atacameños' traditional water management techniques. At present, local communities still practice agriculture but for household consumption. One current risk (to human well-being and ecosystem health) is mono-cropping.	Cropland distribution: Hay: 73.4% (alfalfa) Vegetables: 13.7% Fruits: 6.7% Cereals: 4.2% Domestic crops: 0.6% Forest: 1.4%
Observatories	The pristine air, extremely low humidity, and the geographical features of the area create excellent conditions for astronomical observations. Observatories generate knowledge (particularly at a global level) and employment, and recent agreements between developers and communities include opportunities for local development. On the negative side, observatories alter the landscape, generate waste, increase access to previously isolated areas, and impose limits on the amount of surrounding light.	ALMA Project, total investment: $555 million over 8 years Social contributions: $700,000 annually for local and regional development projects, and national scientific projects. Locally: about $183,000 for health and education projects in San Pedro de Atacama and for productive development for the indigenous community of Toconao.

Caribbean Sea

(See color version of locator map in Appendix A.)

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Lead institutions: University of the West Indies (UWI), The Cropper Foundation (TCF), The Institute of Marine Affairs (IMA), Caribbean Conservation Association (CCA), UNEP Regional Office for Latin America and the Caribbean (UNEP ROLAC), Caribbean Agricultural Research and Development Institute (CARDI), Island Resources Foundation (IRF).

The Advisory Committee of potential users of the assessment includes the Secretariats of the Association of Caribbean States (ACS), CARICOM, the United Nations Economic Commission for Latin America and the Caribbean (UNECLAC), and the Caribbean Conservation Association.

Time period: The time frame evaluated for key ecosystem services were the following: fish production (1950–2000); desalinated water (1992–2000); coral reef cover (1977–2002); amenity value (1990–2003); and climate regulation 1910–2000).

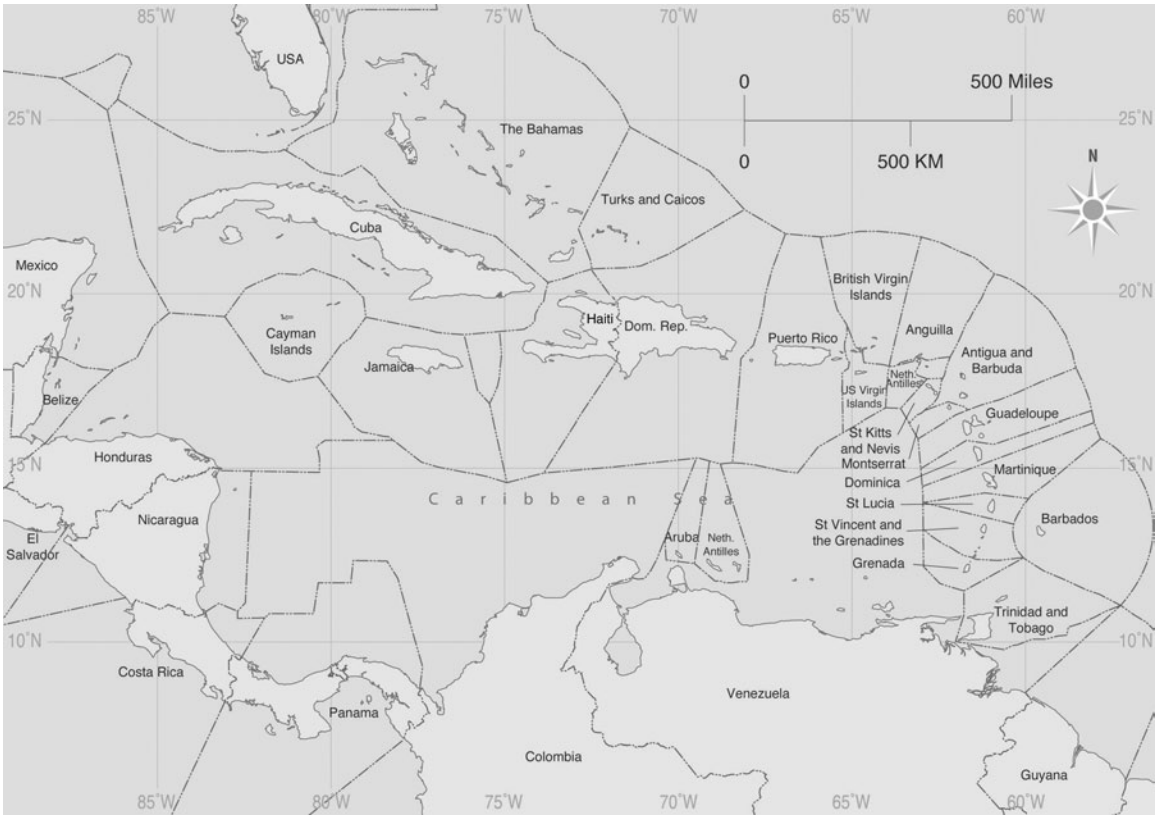
Four scenarios were developed to the year 2050: Neo-plantation Economy, Quality over Quantity, Diversify Together, and Growing Asymmetries.

Summary of important findings:

Fish production. It is moderately uncertain whether increasing efficiency of fish capture through the increasingly widespread use of gill-netting, purse-seining, long-lining and trawling involving local fishers inshore and foreign fleets offshore may have been the cause of major fluctuations in fish catches since the 1980s and of a change in the trophic structure of the Caribbean Sea ecosystem. In Central America and the insular Caribbean the number of people actively fishing increased from 194,278 in the 1970s to 504,913 in the 1990s. Per capita consumption of fish in the region is approximately 15 kilograms, but is highest in the insular states where the average per capita consumption is 19 kilograms, which is well above the world average. The export value of fish and fisheries products increased from $400.6 million in 1976 to $1.6 billion in 2000. The U.S. market is the major destination of most exports from the Caribbean. Export products are dominated by high-value commodities such as shrimp, spiny lobster, tunas, snappers and groupers, and queen conch, which command premium prices in the international market.

Desalinated water. About 3% of the world total of desalinated water is produced from the Caribbean Sea; 92.5% of this desalinated water is utilized by the insular Caribbean countries mainly to solve distribution problems and satisfy tourist demand. The value of the water produced is conservatively estimated at about $317 million per annum. This is an indicator of the replacement cost of this ecosystem service, which is normally sourced from terrestrial watersheds.

Coral reef cover. From 1977 to 2001, typical live coral cover has with high certainty declined from more than 50% in 1977 to about 10–15% in many shallow Caribbean Sea reefs. Studies in 2004 suggest that reefs in waters deeper than about 10 meters and also far from land or next to small populations are much healthier.



Map of Caribbean Sea with Exclusive Economic Zones of Surrounding Countries (The Nature Conservancy)

Amenity value. With high certainty, data from the World Tourism and Travel Council show that relative to its size, the Caribbean scores highest in several key categories when its dependence on tourism is compared with other regions on a global scale. Thus the Caribbean may be the region in the world most dependent on tourism for jobs and income. In 2003, the Caribbean's travel and tourism economy accounted directly and indirectly for: 1,857,000 jobs representing 12.0% of total employment; $23.1 billion of GDP, equivalent to 13.0% of total GDP; $16.2 billion of exports services and merchandise, or 16.5% of total exports; and $7.6 billion of capital investment, or 22.3% of total investment

Climate regulation. Elevated sea temperature episodes in the last decade are the most likely cause of increasingly frequent occurrences of coral reef bleaching in the Caribbean. Since 1998, it is known with high certainty that the region has seen a trend of increasing frequency of tropical cyclones. Deaths and damage to property and ecosystems have also increased incrementally due to interaction with rapid urbanization on the coast.

Major funding: MA, IDRC, UNEP ROLAC.

Central Asia Mountain Ecosystems

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Lead institution: Regional Environmental Center for Central Asia

Time period: The period assessed is 1999–2004. Scenarios are projected to 2030. The project completion date is planned for December 2006.

Intended audience: Governments of the Central Asian states; international and national public organizations; nature users and persons using ecosystem recreational and aesthetic services; population of mountainous areas; mass media; educational, scientific, cultural, and health institutions; local governments; environmental organizations.

Goal: To ensure conservation of mountain ecosystems and sustainable development of the Central Asian sub-region on the basis of continuous effective regional policy efforts designed to improve the interaction of society with ecosystems. Project tasks include the following:

- analyzing the current status and magnitude of human-caused transformation of the Central Asia mountain ecosystems at the local, national, and regional levels;
- identifying causes and effects;
- assessing the capacity of mountain ecosystems to provide goods and services;
- developing and approving a toolbox for an ecological assessment and examination of actions designed to reduce negative influences on ecosystems;
- developing scenarios of possible ecosystem changes depending on adopted decisions;
- developing recommendations for decision-making and planning related to conservation and restoration of mountain ecosystems in Central Asia.

Project components:

- Northern part of Western Tien Shan, near Almaty city (Republic of Kazakhstan)
- Catchment basin of Talass (Kyrgyz Republic)
- Vorzob gorge, Southern slope of Gissar mountains (Republic of Tajikistan)
- Kopet-Dag reservation and surroundings (Turkmenistan)
- Gissarskiy reservation and surroundings, Western Pamir-Alay (Republic of Uzbekistan)

Condition of ecosystem services in the Central Asian mountains:

Genetic resources. The mountains of Central Asia, due to their geographic location in the heart of the sub-region and a comprehensive range of altitude belts, are characterized by high biological diversity at the ecosystem, population, and species levels. Mountain ecosystems serve as the place of origin for many cultivated plants and animal breeds, refugia of plants and animal species, and a gene pool for a number of globally important species.

Water. The mountains of Central Asia are a unique source of fresh water. Runoff of the large rivers in the regions, such as the Ili, Shu, Talas, Syrdarya, Amudarya, Zeravshan, Atrek, Karatal, Aksu, Lepsa, etc., is formed in the high altitude mountains. A cascade of water reservoirs used for irrigation and power generation controls the runoff. Many small rivers start in the foothills as a result of underground runoff discharge. Their water is used to irrigate agricultural land in the piedmont valleys.

Forestry resources. The main forestry resources of the region are concentrated in the mountains of Central Asia. They are the source of timber and fuel wood, fruits, berries, and medicinal plants, and the habitat of various wild animals. The Tien Shan Mountains have a unique spruce forest belt formed by the relic species of Tien Shan spruce. The Western Tien Shan still has a lot of Zeravshan juniper open woodlands. Considerable areas are under wild fruit-bearing forests and represent the genetic centers of origin for cultivated varieties of apple, pear, pomegranate, apricot, etc. Mountainous forests play an important role in water regulation, landscape control, oxygen production and carbon dioxide absorption.

The Central Asia mountains are surrounded by a desert zone. Foothills and low altitude areas are overpopulated due to more favorable climatic conditions and a better supply of water, land, pasture, forest, and other resources. The mountain ecosystems play a leading role in sustaining the livelihood of populations in the mountains and adjacent valleys (providing water, fuel, feed for domestic animals, treatment and recreational facilities, etc.)

Mountain ecosystems appear to be highly vulnerable and sensitive to human pressures due to the high rate of substance and energy transfers from higher to lower altitudes, which contributes to the threat of natural and human-caused disasters. Increasing exploitation of mountain ecosystems and degradation of biota result in the disruption of ecosystem linkages and the consequent reduction of the regulating functions of ecosystems. The negative effects of human activities in the mountains are demonstrated by an increased occurrence of natural disasters (mudflows, landslides, floods), extremely fast biodiversity losses, water resource reduction, and soil degradation. This, in turn, makes the mountains less appealing in terms of tourism and recreation, negatively affects the revenues of the people populating both the mountains and surrounding valleys (deserts), and promotes the processes of ecosystem destruction. Low living standards and population growth often force the Central Asia governments and populations to compromise, accepting progressive environmental degradation to satisfy the urgent needs of life. Resource depletion ultimately results in further impoverishment of the population.

Coastal British Columbia, Canada (Coastal BC)

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Project team and institutions: The assessment was conducted by the Coast Information Team (CIT), consisting of a management committee of representatives of the British Columbia Provincial Government (David Johns, Ken Baker [Co-Chair], Gary Reay), First Nations (Art Sterritt [Co-Chair], Dallas Smith), environmental NGOs (Dr. Jody Holmes, Ivan Thompson, Tom Green), forest products companies (Rick Jeffery, Corby Lamb, Patrick Armstrong, Linda Coady, Hans Granander), and the community at-large (Graem Wells, Bill Beldessi), a secretariat (executive director Robert Prescott-Allen, program manager Melissa Hadley), and ten project teams: Ecosystem-based Management (EBM) Framework (led by Alex Grzybowski), EBM Planning Handbook (Dan Cardinall), Hydroriparian Planning Guide (Dr. Mike Church, Karen Price), Scientific Basis of EBM (Dr. Andy MacKinnon), Ecosystem Spatial Analysis (Dr. Reed Noss and Chuck Rumsey), Ecosystem Trends Risk Assessment (Dr. Rachel Holt), Cultural Spatial Analysis (Dr. Bob Lee), Economic Gains Spatial Analysis (Dr. Doug Williams, David Hall), Well-being Assessment (Robert Prescott-Allen), and Policy and Institutional Analysis (Dr. George Hoberg). The peer review chair was Dr. Rod Dobell, Emeritus Professor of Public Policy, University of Victoria.

Time period: The period assessed is 1990–2000. The project timeframe was January 2002–March 2004.

Intended users: Sub-regional and First Nations planning processes; provincial and First Nations governments.

Products: The CIT produced four EBM guides and six regional and sub-regional analyses. The former consisted of EBM Framework, EBM Planning Handbook, Hydroriparian Planning Guide, and Scientific Basis of EBM; the latter included Ecosystem Spatial Analysis, Ecosystem Trends Risk Assessment, Cultural Spatial Analysis, Economic Gains Spatial Analysis, Well-being Assessment, and Policy and Institutional Analysis.

Main findings:

Ecosystem services and human well-being. The region's ecosystems provide supporting and regulating services that are essential for human well-being. In rural societies, major provisioning and cultural services—notably those required for sustenance—are identical. However, the assessment distinguished *economic services* (sources of income and employment with a direct monetary value) and *cultural services* (all other material and nonmaterial contributions to human well-being, including the provision of food). The main economic services are provision of resources for fisheries and food production, logging and wood production, and tourism, contributing from 17% to 56% of employment income (depending on sub-region)—lower than it was in 1990, except in Upper Mid Coast, where the contribution to employment income has risen. The largest source of employment income is logging and wood production, apart from fisheries and food production in the Outer Central Coast. The main cultural services are provision of land and marine plants and animals that are major sources of sustenance for First Nations and nonaboriginal communities (fishing, hunting, and plant gathering have both nutritional and cultural value in local cuisines and as activities that express and affirm aboriginal and rural lifestyles); raw materials for traditional arts, crafts, and medicines; the sites of origin stories, crests, dances, legends, and names, as well as traditional fishing, hunting, gathering, and dwelling places; and places of artistic heritage and aesthetic and recreational value.

Conditions and trends: ecological integrity and ecosystem services. The supply of ecosystem services depends on maintaining the ecological integrity of land, fresh water, and marine ecosystems and the atmosphere. Ecological integrity is medium poor, based on scores for ecosystem diversity, species and genetic diversity, environmental quality, and provisioning and cultural services. Declining populations of resource species and increasing risk to rare ecosystems and species are the main signs of impaired ecological integrity. Although the protected area system is already substantial, it does a poor job of representing the region's land and marine diversity, and in two subregions is entirely inadequate. Declines in resource species have a direct impact on economic and cultural services. Increasing risk to rare ecosystems and species is evidence of damage to ecological integrity that may not affect economic and cultural services but could impair supporting and regulating services.

Conditions and trends: human well-being. Human well-being is medium, based on scores for population and health, wealth, knowledge and culture, and community. The main reasons are: excessive population fluctuations, inadequate employment income, high proportions of low-income households, weak economic foundations (poor access to resources and limited business diversity), mediocre knowledge and education, insecure access to cultural places, lack of power over decisions that affect local livelihoods, low expectations of local governance, and social problems manifested by a high proportion of deaths from self-destructive behavior (drugs, alcohol, suicide) and high rates of domestic violence. Over the past decade, most of these factors have worsened (notably population fluctuations, employment income, low-income households, economic foundations), although other conditions have improved (education levels and crime rates).

Drivers of change. The main human impacts on the ecosystem are uses of provisioning and cultural services through harvest pressure and the introduction of exotic species. These are driven by needs for sustenance and to earn a living, a desire to make money, provincial revenue demands, and the pursuit of recreational enjoyment—or, in general terms, people's needs and wants. In turn, the needs and wants which count the most depend on market powers and access to local resources. Metropolitan populations dominate access to, and decisions on, local resources. Local populations have a small share of the benefits from local resources compared with the large share flowing to corporations outside the region. Local populations do not drive change; change drives populations—into or out of the region, depending on whether the change is for good or bad. The impacts of human drivers on the ecosystem may be dampened or intensified by ecosystem drivers—the dynamics of populations and species, biogeoclimatic processes, and disturbance regimes.

Responses. Six sets of responses are proposed:

- increased ecological protection;
- providing cultural security by guaranteeing access to places needed for sustenance and protecting places needed for other values (such as heritage and nonconsumptive recreation);
- improving economic development by concentrating on areas with the highest potential for economic gain from timber, tourism, nonwood forest products, fisheries, and minerals;
- combining ecosystem and cultural conservation and economic development through ecosystem-based management planning;
- regular monitoring and periodic assessment of plan implementation, together with a research program to fill major knowledge gaps and reduce uncertainty; and

- better governance through new institutions and policy instruments, including sub-regional decision-making bodies, an independent regional science body, making EBM objectives legally binding, public and private conservation financing, and an independent dispute resolution body.

For further information: Full information on the assessment, together with the four EBM guides and six regional and sub-regional analyses, are available from http://www.citbc.org

Budget: CA$3.3 million, funded by the Province of British Columbia (58%), environmental groups (18%), forest products companies (18%), and the Federal Government of Canada (6%).

Colombia

Ecological Function Assessment in the Colombian Andean Coffee-growing Region

(See color version of locator map in Appendix A.)

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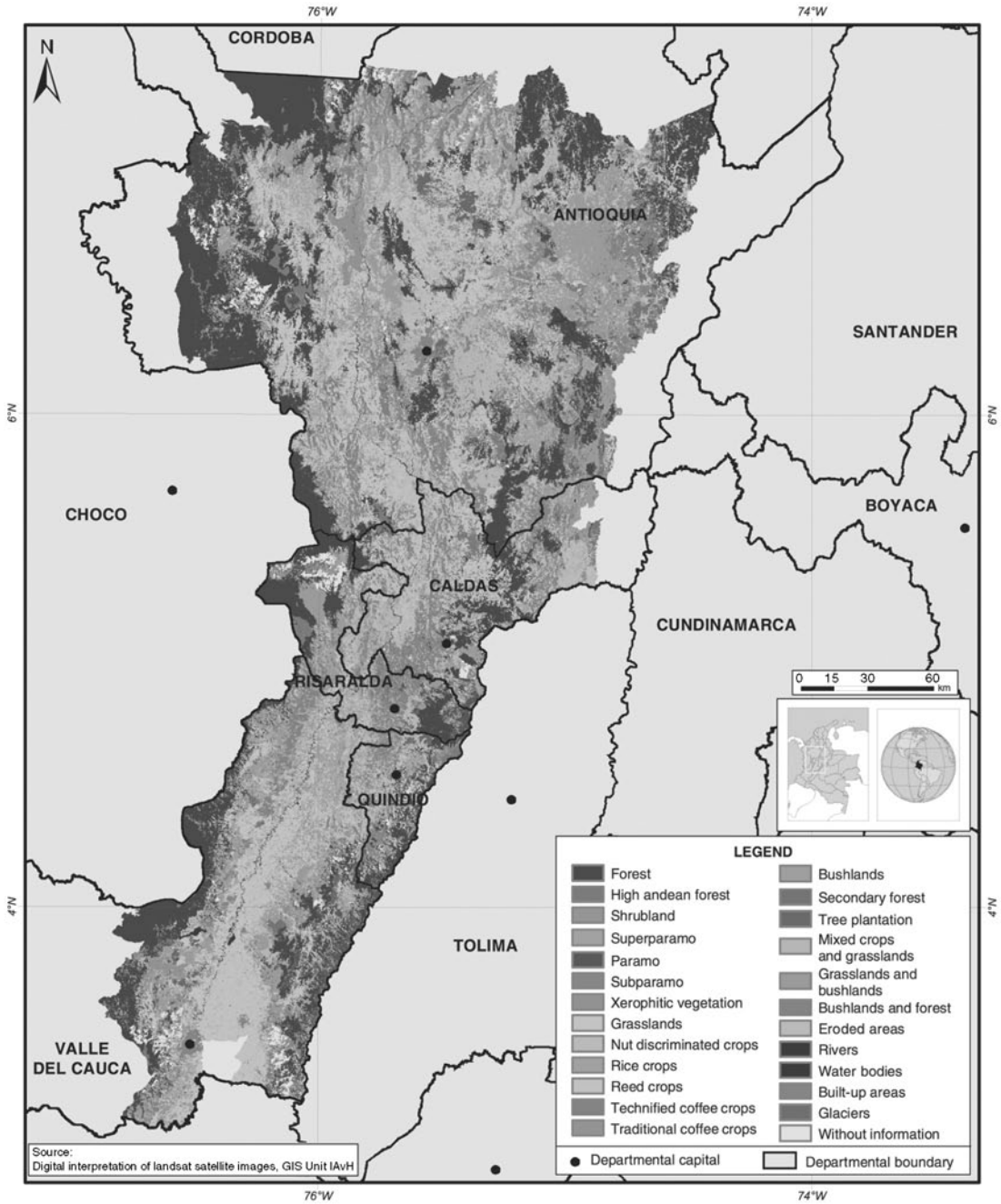
Project team: Dolors Armenteras, Nestor Ortiz, Alexander Rincón, Nestor Ricardo Bernal, Edersson Cabrera, Diana Patricia Ramírez, and Nelly Rodríguez of the Humboldt Institute, and Margarita Jaramillo of Cenicafe with the collaboration of several Cenicafe researchers.

Time period: The period assessed is 1985–2003. Scenarios are projected until 2025. Completion of the assessment is uncertain, dependent on funding.

Intended audience: Sub-national and local decision-makers.

Issues addressed:
This ecological function assessment of the coffee-growing region of Colombia was undertaken as a spatial-temporal comparative study of several social, economic, demographic, and environmental variables at different scales. The relationships between drivers of ecosystem changes, ecosystem services, and human well-being have been identified for the



Ecological Function Assessment, Colombian Andean Coffee Growing Region

Colombian situation and include coffee-related factors as well as others that might have an important effect on human well-being.

Drivers of change. Ecosystem services significantly contribute to the well-being of the human population in coffee-growing regions and to their economic productivity. This assessment identifies indirect drivers that can have an effect on those factors that directly influence ecosystem processes (direct drivers) in the region, such as economic activity and the population which themselves become the main factors of changes in natural and seminatural cover, greater use of pesticides and fertilizers, introduction of new species, etc. *Indirect* drivers studied include total population, population density, economic activity indicators, national gross domestic product, environmental NGOs, and other associations. *Direct* drivers studied were land cover change and phytosanitary aspects related to coffee production.

Human well-being was addressed by looking at the population quality of life, percentage of households with unsatisfied basic needs, poverty line, mortality rates per cause of death, and educational issues such as illiteracy rate and education levels.

Ecosystem services. Ecosystems and their services have traditionally been undervalued, and they are often ignored in regional decision-making processes. The extent, location, and trends in transformation to and from ecosystems were studied, as well as the location of rapid changes in the area. Supporting and provisioning services such as biodiversity and coffee production were also analyzed. In 2002, Colombia was the third largest coffee producing country (out of 79), with 9% of world production, representing around 805,000 hectares, with an average production of 820 kilograms per hectare.

Correlation analysis and important findings. This assessment attempts to offer region-specific information to support decision-making in the area and to summarize possible current conditions and some trends in the coffee region. It focuses on quantifying ecosystem and population changes and analyzing changes in the structure of ecosystems that have taken place over time in the area, pointing out how they might be related to changes in the area's demographic and economic structure. The smallest spatial unit for which most socioeconomic and demographic data are available is the *municipio,* a purely administrative frontier. In order to analyze the impact of human pressures on natural ecosystems and the possible determinants of ecosystem changes we undertook correlation analysis (Pearson correlation coefficient) of 57 environmental, demographic and socioeconomic variables.

For further information: Part of this study is published as: Rincón, A. Armenteras, D., Ortiz, N., Ramírez, D y Cabrera, E. (2004). Indicadores de Seguimiento y Evaluación de la Política Nacional de Biodiversidad en la zona cafetera occidental: avances metodológicos y resultados.'' Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. Serie: Indicadores de Seguimiento y Evaluación de la Política de Biodiversidad. 86 pages. ISBN: 958-8151-29-5

Funding: Instituto de Investigación de Recursos Biológicos Alexander von Humboldt.

Eastern Himalayas

(See color version of locator map in Appendix A.)

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Location: The Darjeeling district, covering an area of 3,149 square kilometers.

Lead institution: Ashoka Trust for Research in Ecology and the Environment (ATREE).

Indirect drivers of change:

Population growth. Population increase over the years has been one of the main problems in the Darjeeling hills, resulting from a number of factors such as uncontrolled family expansion, immigration from other regions of India as well as other nearby countries due to the establishment of the tea plantations, and Darjeeling being a prominent tourist destination.

Family fragmentation. The village communities have started moving toward nuclear-type families, resulting in land that is more fragmented and less suitable for the practice of subsistence agriculture. In 1956, Karmat village had 24 houses; in 2003, as a result of families splitting up, the number of houses in the village had increased to 65, with an average size of 6 family members.

Economic status. Economic self-sufficiency and alternative livelihood options are severely lacking in the hills due to the lack of resources and the absence of alternative job opportunities. Villagers located in mountainous terrain at altitudes of between 1,800 and 3,600 meters have to purchase basic necessities including staple foods such as rice and dal (pulses) from the nearest urban centers. Price fluctuations of these staples, along with transportation costs, encourage villagers to sell fuelwood to cope with the situation.

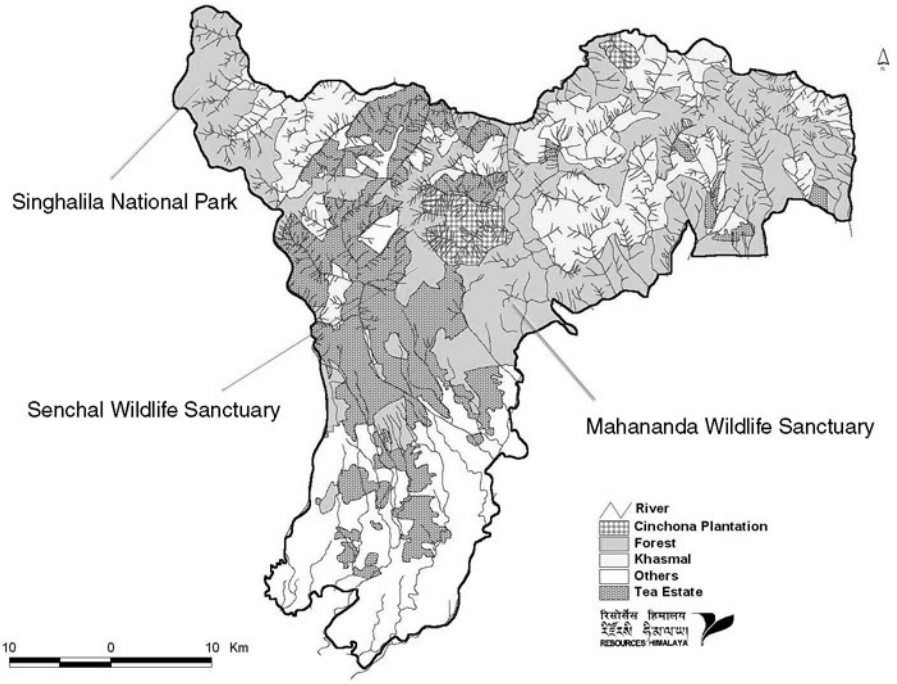
Policies, institutions, and processes. Despite implementation of a wide range of policies, institutions, and processes, the government's capacity-building measures have not achieved significant diversification of livelihood patterns in the villages. Often the secretaries of various committees are nominated by the government, and villagers are not made aware of the activities underway and the budget allocated.

Change in local land use pattern. Family fragmentation has resulted in fragmentation of agricultural land and clearing of forest land for settlement. This land use pattern has also played a major role in the degradation of ecosystems and in causing land slides and flooding. The recent proposed sites of Teesta Dam Stage IV and Ramam Hydel Project and Nuclear Laboratory will result in the submergence of villages and the fragmentation of habitats for flora and fauna. The Kalikhola mini hydel project will lead to the loss of faunal habitat, which can accentuate the conflict between humans and animals in the villages and lead to loss in agricultural production.

Ecosystem services:

Non-wood forest products (fruits, vegetables, and medicinal plants). The village communities in the protected areas extract NWFPs at subsistence level. Woody and fibrous construction materials are required for agriculture implements, cattle sheds, and repair of houses. Various studies have shown that there has been an overextraction and exploitation of medicinal plants such as *Aconitum bisma, Aconitum spicatum, Dactylorhiza hatagirea, Heracluem wallichii, Neopicrorhiza scrophulariiflora, Panax pseudoginseng subsp himalacus, Podophyllum sikkimense,* etc.

Water. Water-related problems are faced by the village communities of the three protected areas in the assessment. The village communities are aware that the problem is due to the felling of trees and clearing of forest in the catchments. Two lakes built inside the Sepahijala Wildlife Sanctuary at the turn of the twentieth century demarcated 447.4 hect-



ares as catchment areas for drinking water supply to Darjeeling town. The catchments were securely protected by construction of barbed wire fencing. Today, the fence is as good as nonexistent. At least 81% of the catchments presently lie denuded. As long as protection was provided to the catchments, nearly 26 streams regularly supplied water to the lake. Today, only 14 of those streams are still flowing, which has resulted in an acute water crisis in Darjeeling.

Soil. Soil fertility has been affected by the use of chemicals like urea and diammonium phosphate; in addition, faulty agricultural practices such as tilling of land during monsoon season have caused the erosion of topsoil. The villages located in the hilly region have not adopted contour bunding in the terraces where vegetables are grown, resulting in landslides and soil erosion.

Responses undertaken: The northern region of West Bengal has a long-standing tradition of symbiotic relationships between the local communities and the forests, but since independence, the government's approach to the local people was mainly confrontational thus leading to severe negative impacts in terms of conflicts between the local communities and the forest departments. This conflict also led to the proliferation of the illegal trade in timber and other ecosystem products. The importance of involving the local people in protected area management was realized in the early 1970s when UNESCO's Man and the Biosphere Reserve Program began to promote the creation of buffer zones between the strictly preserved areas and human settlements. India's Department of Environment created a Board of Ecodevelopment in 1982–83, after the World Congress on National Parks in Bali gave impetus to the objective of linking protected area management with economic activities of the local people by advocating the implementation of joint management between the communities which traditionally managed these forests and the protected area authorities. Following this, the Joint Forest Management Program was initiated through the National Forest Policy of 1988. This concept extended the ''ecodevelopment'' program to protected areas, not only reducing the impact of people on protected areas but also fostering better communication between local communities and the management authorities of protected areas

Scenarios: The ecosystem in the Darjeeling Himalayas has been under tremendous human pressure over the years. Even though some remedial measures have been initiated involving the communities and the government agencies, success has been only partial. The consequences of the continuing exploitation of ecosystem services, if unchecked, will have a major impact on the state of the environment. The assessment developed four plausible scenarios for the region, calling them ''No Action,'' ''Varied Experiments,'' ''Technological Fix,'' and ''Development Fix.''

Time frame: The assessment was initiated in 2002 and is on-going.

Sinai, Egypt
Local knowledge, biodiversity, and poverty alleviation

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Ecosystem services:

Cultural services. The survival of local, indigenous knowledge is one of the main factors that enables Bedouins to withstand the harsh environment of Sinai. Management of agricultural systems, conservation of valuable native plants, and small handicrafts are illustrative examples of the utilization of vital knowledge about the environment that contributes to the well-being of local populations. Local people utilize intercropping systems to gain maximum yield, to ensure the sustainable exploitation of natural resources (water and land), to protect themselves against environmental risks such as unexpected drought or disease. In particular, Bedouins may bring some distant species to their local areas to increase the diversity of plants and to use them in a variety of ways, including for medicine and fodder.

Grazing. Grazing contributes to the well-being of Bedouins and supports their existence in Sinai's unusually arid ecosystem. Related ecosystem goods include meat and milk, which supply Bedouins with their protein needs. Transport is partially dependent on camels; organic manure is one of the grazed livestock products that is often used as a source of heat and cooking, and animal skin is used for the construction of shelters. Animal wool is used as the primary material to produce a variety of household and farming tools. Wool is also the backbone of some handicraft industries such as rugs, and can be used in bedding and clothing.

Condition and trends: Condition and trends of ecosystem services are assessed over the past 10 years. The lack of available data on led to the use of information from the local Bedouin inhabitants. The long periods of drought that Sinai has had during the last 7 years had a significant impact on ecosystem conditions. Natural flora provide a source of provisioning services that are crucial to local populations, in the form of food, fodder and medicine. Some of the most well-known plants have almost disappeared due to overharvesting as well as drought. Grazing has declined due to low levels of rainfall, as a result of the decrease in populations of local plants normally eaten by the grazing animals. The role of local knowledge to support human life in the Sinai desert is declining to some extent due to changes in lifestyle. Drivers include education, immigration, employment, and changing sources of income.

Scenarios: Scenario development will be based on public participation to allow users to have a say in developing scenarios.

Responses: The analysis of responses will entail the participation of stakeholders and decision-makers, including Bedouins. Responses will be designed to maintain various components of human well-being including health, food security, economic security, and equity. The main strategies that will be undertaken to achieve these goals include the promotion of awareness of the local people at selected sites with the need and importance of nurturing biodiversity, training courses and capacity-building, rehabilitation of some wild species, formation of a Bedouin biodiversity association, and crop biodiversity and management.

Funding: Ford Foundation, $150,000; UNEP, West Asia Office, $75,000.

Fiji

(See color version of locator map in Appendix A.)

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Location: Three sites are included in the assessment: Gau, the fifth largest island in the country with pristine natural ecosystems; the Greater Suva Harbor, the lagoon surrounding a large urban center; and the Coral Coast, a region in transition with extensive tourist development.

Lead institutions: Marine Studies Programme (MSP), Institute of Applied Science, and the International Ocean Institute-Pacific Islands (IOI-PI) at the University of the South Pacific.

Focal issues: The assessment in Fiji will allow the exploration of existing resource-use practices, the examination of the changes and trends affecting ecological conditions, and the formulation of the various response options. Involvement of local communities is a major challenge.

Key features of the assessment: Fiji is a developing country where the main economic activities include agricultural production, tourism, and the exploitation of natural resources. The population of Fiji is growing at the rate of 2.3% annually and this has led to serious environmental problems that threaten the ecological integrity of local ecosystems. The assessment sites represent areas of different levels of economic development. Some threats include destructive fishing, coastal erosion, logging, industrial pollution and waste disposal.

Fijian Assessment

Bajo Chirripó, Costa Rica
Local ecosystem assessment of the higher and middle Chirripó river sub-basins, Cabécar Indigenous Territory

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Project team: The assessment was conducted by: Abraham García, Flor Morales, Elizabeth Sanabria, Otilio Mora, Roger Espinoza, Carlos Artavia—members of the Cabecar indigenous community; and Carlos Sevilla, Esther Cámac, and Fabricio Carbonell—consultants.

Project time frame: Planning began in January 2003 and the project was formally launched in June 2003.

Ecosystem services assessed: Culture and biodiversity in holistic integration

This is a user-driven assessment conducted in large part using the traditional knowledge of the inhabitants of the assessment areas. The area is part of the La Amistad Biosphere Reserve of Costa Rica, established in 1982 and declared a World Heritage site one year later. It is located in the buffer zone of the Caribbean basin, in the sub-basin of the Chirripó River. It is also a part of the Mesoamerican Biological Corridor due to its important ecosystems, with six life zones and species diversity of high conservation value.

Traditionally this population conserves deeply-rooted ancestral knowledge on the uses of ecosystems, and lives in a tropical humid forest with dense cover. Their territory contains 48,000 hectares of pristine forest that is currently threatened by timber activities, poaching, pollution, and ecosystem fragmentation due to the unsustainable agricultural practices of non-indigenous people.

We started by recovering the stories and histories from the elders about the habitat, its creation, and the norms that regulate its use. We then complemented this knowledge with scientific literature and produced a first interpretation of the relation of ecosystems and human well-being from the Cabécar perspective. We then validated the information in community gatherings convened by elders in other Cabécar communities.

What we came up with first was a description of the broad cosmovision of the Cabécar people. Some elements of it are: (1) Earth is a circle surrounded by sea; there is a balance between upper and lower worlds; (2) habitat as a conic house; (3) special areas and places are protected by guardians that regulate access and use of resources; and (4) each living entity is a seed that deserves respect. Human beings are maize seeds.

Given this cosmovision, the relationship between ecosystems and human well-being needs to be understood as taking one of three possible forms: (1) Interrelation—human beings are part of habitat and habitat is part of human beings; (2) *reciprocity*—among human beings (men-women, children-elders) and with the environment; and (3) *respect*—codes, norms, myths, beliefs, dreams.

One of the main qualities of ecosystems is ''abundance''—these are places full of life, places of generation of life. Access to this abundance is regulated by ''guardians'', which are not human. So the norms that control access are within the ecosystem itself. Also, among the constituents of human well-being, the main ones identified are cultural security (identity, spiritual, health, knowledge), food, territorial security, social and environmental reciprocity.

Funding: The MA, SwedBio, and Ixacavaa Association are providing financial support.

Forest and Agroecosystem Tradeoffs in the Humid Tropics (Tropical Forest Margins)

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This cross-cutting assessment focuses on the landscape mosaics (comprising both forests and agriculture) where global environmental problems and poverty coincide at the margins of the remaining humid tropical forests. Deforestation often is blamed on the slash-and-burn practices of migrant smallholders, millions of whom do clear and cultivate small areas of forest by this method. However, other groups also are involved, including plantation owners, other medium- and large-scale farmers, ranchers, loggers, and state-run enterprises and projects.

Assessment domain: tropical forest margins in ecoregions mapped by the World Wide Fund for Nature that contain benchmark sites of the Alternatives to Slash-and-Burn Program in the Peruvian Amazon, the Western Amazon of Brazil, an associated site in the Eastern Amazon of Brazil, the Congo Basin of Cameroon, Northern Thailand in Montane Mainland Southeast Asia, and the islands of Sumatra in Indonesia and Mindanao in the Philippines. ASB benchmark sites are areas (roughly ranging from one hundred to one thousand square kilometers) of long-term study and engagement by ASB partners with households, communities, and policy-makers at various levels. Human population of the specific benchmark sites ranges from ten thousand to one hundred thousand and, comparing across sites, densities range from less than 20 to over 170 persons per square kilometer. All the ASB benchmark sites and corresponding WWF ecoregions are in the humid tropical broadleaf forest biome.

In a class by themselves as the richest terrestrial vegetation by far, conversion of these forests leads to the greatest species loss per unit area of any type of land cover change. Preliminary estimates indicate more than 500 million people live within this humid tropical forest biome; ongoing refinements based on newly released data likely will increase that figure substantially. Most are poor households directly dependent on forest resources and agriculture for their livelihoods. Other poor households suffer indirectly from waste of these resources and environmental degradation.

Key users of the assessment: national and regional policy-makers, rural communities, national research organizations, and universities.

Driving forces of land use and land cover change: Deforestation has no single cause but is the outcome of a complex web of factors whose mix varies greatly in time and space. Shifting cultivation for subsistence food production is seldom the main cause of tropical deforestation. Other forms of agricultural expansion—practiced by smallholders and large landowners alike—tend to be much more important. But the most significant determinant of all is how these land uses interact with and are affected by macroeconomic forces, access to markets, and a host of other policy and institutional factors. Changes in land use and land cover are, in turn, major drivers of changes in ecosystem services in the tropical forest margins. Assessment of driving forces arising from human activities, institutions, and policies is largely complete and *these findings are well-established*.

Ecosystem services and human well-being: Conditions and trends

Assessment topics include provisioning services, of which food supply received particular emphasis from users; the regulating of services carbon storage, water supply, and soil nutrient supply; and biological diversity. Specific assessment questions have been developed further through stakeholder consultations that have been completed in Brazil, Indonesia, and Cameroon and that are nearly complete in Peru and Thailand. Because the assessment of conditions and trends is ongoing, the following summary of *preliminary findings on specific conditions and trends are established* (for ASB sites) *but not yet complete* (regarding synthesis of other scientific results).

Food and other provisioning services. The relative importance to local livelihoods of the food, timber, fodder, and other goods produced in mosaics of land uses at the forests margins differs dramatically among sites in South America, Central Africa, and Southeast Asia. Analysis of yields of the main products from representative land uses and the profitability of those land use alternatives are complete for ASB benchmark sites in five countries spanning the humid tropics. Work is underway to scale up these results to assess the relative importance of the tropical forest margins as suppliers of these key goods to regional and national economies and to international markets.

Water. There are trade-offs between total water supply and the seasonal pattern of river flows (including flooding risks) because forests use more water than other types of vegetation in the humid tropics. It is important to disentangle watershed issues when considering how land use change affects them. New tools and data sets exist that can eliminate some of the uncertainty about cause and effect at meaningful scales for policy-makers. ASB partners have employed a nested set of models (from sub-catchment to basin to pantropic scales) to apply the best available data and tools to assessment of these relationships. See http://www.asb.cgiar.org/BNPP/phase2/bnpp_phase2_general.htm.

Carbon stocks and biological diversity. No forest-derived land use can match the carbon storage or biological diversity of natural forests, but the agricultural uses that follow forest conversion differ significantly with respect to delivering these ecosystem services. The rubber agroforests of Sumatra and cocoa agroforests in Cameroon are examples of systems with levels of biodiversity far higher than those in monocrop tree plantations or annual cropping systems, though not as high as natural forests. These agroforests also store substantial levels of carbon relative to the other systems, yet less than half that of natural forest. In contrast, the pasture-livestock systems that dominate land-use in deforested areas in the Brazilian Amazon have much starker trade-offs, providing attractive opportunities for smallholders but large losses of carbon storage and biodiversity. See http://www.asb.cgiar.org/publications.shtm #WGReports.

Trade-offs between ecosystem services and human well-being. Striking an equitable balance between the legitimate interests of development and equally legitimate global concerns over the environmental consequences of tropical deforestation is difficult. ASB has developed a tool, called the ASB Matrix, for assessing these trade-offs, and has applied it at five benchmark sites. Poverty reduction in most of the tropics depends on finding ways to raise productivity of labor and land through intensification of smallholder production systems. Although there may be opportunities to alleviate poverty while conserving tropical rainforests, it is naïve to expect that productivity increases necessarily slow forest conversion or improve the environment. See http://www.asb.cgiar.org//PDFwebdocs/Policybrief5..pdf.

Responses: The challenge of ASB, and of this assessment, is to identify innovative technologies, institutions, and policies that can reconcile

two great issues of our time: tropical forest conservation and poverty reduction. The assessment focuses on responses aimed at balancing these tradeoffs between ecosystem services and human well-being that characterize the tropical forest margins, including land and tree tenure reform (http://www.asb.cgiar.org/PDFwebdocs/PolicyBrief2.pdf); incentive schemes for environmental services that target benefits to the rural poor, such as payments for environmental services (http://www.worldagroforestrycentre.org/sea/Networks/RUPES); negotiation support systems to better link science with social and political processes, thereby accelerating learning and discovery of workable options (http://www.consecol.org/vol5/iss2/art21); and landscape restoration (http://www.unep-wcmc.org/forest/restoration/globalpartnership) to revive habitats and restore ecosystem functions while reducing poverty by creating valuable assets for the rural poor. This work will follow on the assessment of conditions and trends and likely will continue in 2005.

Scenarios capacity building: ASB partners have limited experience with participatory formulation and use of scenarios. To fill this gap, a workshop was held in late 2004 to train ASB facilitators. Planned follow-up to the workshop includes local and national scenarios activities at ASB sites and a ''virtual'' on-line event to compare results and distill lessons learned in 2005.

Time frame: Pilot assessment: 2003. Main assessment: 2004. Review and outreach: 2005.

Key references:

http://www.asb.cgiar.org. This website includes ASB *Policybriefs,* technical reports, country synthesis reports and a searchable database of over 500 ASB publications.

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- Tomich, D.E. Thomas, and M. van Noordwijk (eds.), *Environmental Services and Land Use Change: Bridging the Gap between Policy and Research in Southeast Asia*. Elsevier Science (in press). Available at http://www.asb.cgiar.org/PDFwebdocs/Environmental_Services.pdf

Funding: This work has been funded by grants from the Millennium Ecosystem Assessment and the World Bank Netherlands Partnership Programme; funding was also provided by the government of the Netherlands and core support was provided by CGIAR, the World Agroforestry Center, and the Earth Institute at Columbia University. ASB partners provided in-kind contributions.

Hindu Kush–Himalayas

(See color version of locator map in Appendix A.)

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Location: The Hindu Kush–Himalayas (HKH) region, stretching 3,500 kilometers over eight countries, from Afghanistan in the west to Mynamar in the east, is home to more than 150 million people and affects the lives of three times as many in the plains and river basins below. The region is not only the world's highest mountain region, but also its most populous.

Lead institution: International Centre for Integrated Mountain Development (ICIMOD).

Objectives: The overall objective is to provide scientifically credible information of ecosystem services to facilitate trade-off and incentive (compensation) mechanisms for poverty alleviation and environmental enhancement in the HKH mountains. Specific objectives include:

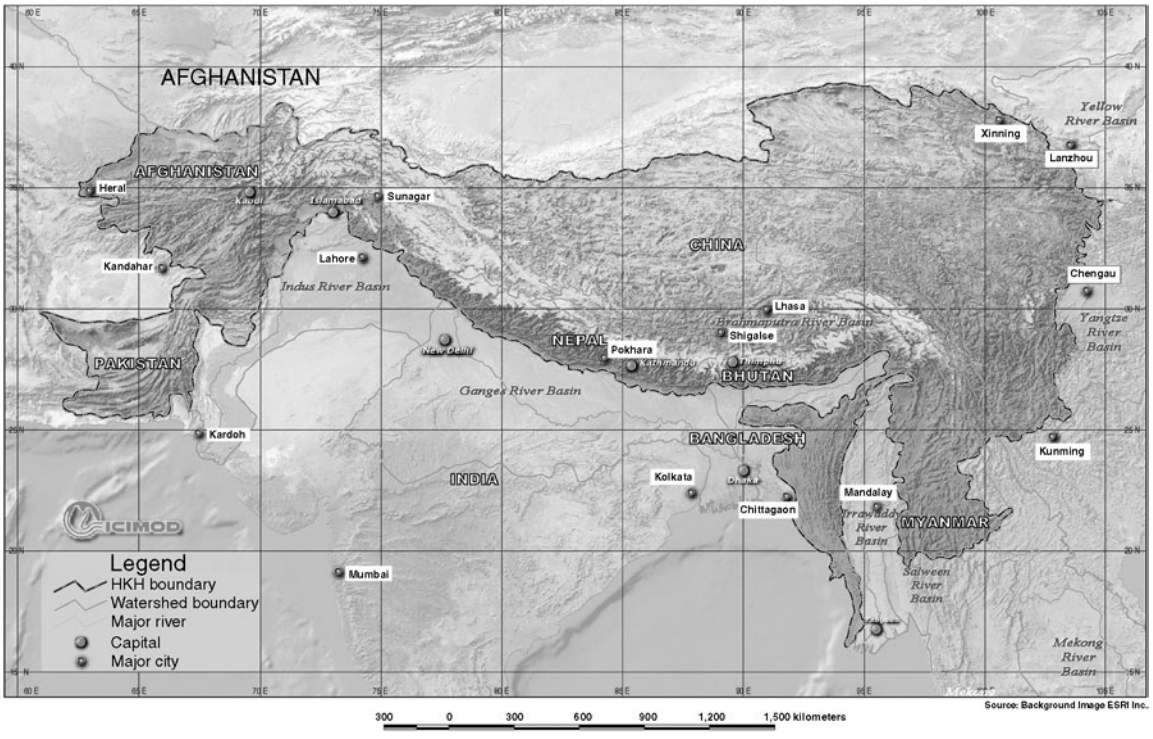
- providing credible information on ecosystem services in terms of provisioning, regulating, and supporting services, and cultural heritage;
- measuring the pace of environmental change and the consequences to local, regional, and global beneficiaries;
- identifying the dominant driving forces for environmental change and explore future trends;
- developing scenarios of the future on ecosystem services;
- identifying policy responses in general, trade-off options at the local level, and incentives (compensation) at national, regional, and global levels;
- catalyzing international negotiations on environmental incentives;
- synthesizing existing knowledge and bridging knowledge gaps;
- building capacity among institutions of the HKH region, particularly on the science-policy interface for the effective use of research findings.

Key features of assessment: The HKH mountains ecosystems provide goods and services that sustain 150 million people living within the region and some 500 million people living downstream. In addition, this mountainous region is vital to sustaining the earth through the following ecosystem services:

- cold source and carbon sink to respond to the threats of climate change;
- sources of water as the birthplace of many large rivers such as Indus, Ganges, Yangtze, Mekong, Yellow and Yaluzanbu;
- genetic resources to the rest of the world and future generations from its rich biodiversity;
- indigenous knowledge of best practices for managing fragile mountain environments;
- cultural and spiritual assets derived from the local geography and history; and
- recreational sites for people from all over the world.

The inherited environmental fragility and social economic vulnerability have put the Hindu Kush–Himalayas on the top of sustainable development agendas. The rapid change of the ecosystem, driven by both natural and anthropogenic determinants, poses unprecedented threats not only to the livelihoods of the local people, wildlife and culture, but also to the global environment.

Budget, time frame: Approximately $2.0 million, of which $0.5 million in-kind is from ICIMOD and member countries and $1.5 million is from donors such as the Italian government and other donor agencies. The assessment is expected to take 3 years.



Hindu-Kush Himalayas

India Local Villages (India Local)

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Time period: The condition and trend assessment is for a 10-year period. The project time frame is 2000–2004.

Ecosystem goods and services assessed:

Study area	Goods and services	Bads and Disservices	Ecosystem Types	Management Context
Southern Karnataka	availability of economically important NWFP species; provisioning of food, water, fuel, fiber; aesthetic and spiritual services	reduction in cultivation area of traditional cultivars; scarcity of fuel and fodder; menace of wild boars, gaurs, and monkeys for agriculture; health problems to people and livestock due to weed plants; drinking water scarcity; vectors like ticks; crop and livestock diseases; siltation of waterbodies; soil erosion	evergreen forests; semi-evergreen forests; scrub forests; plantations; grasslands; orchards; flowing waterbodies; wells, borewells; lakes; ocean; sea shores	presence of National Park; no official rights of local people over forests; existence of private management systems like leaf manure forests
Vidarbha	availability of economically important NWFP species; provisioning of food, water, fuel, fiber, medicinal plants; aesthetic and spiritual services	menace of wild boars for agriculture; reducing wild food	moist deciduous forests, scrub forests	NISTAR—usufruct rights over forests; ownership over "minor forest produce"

Summary of important findings and methodologies used in the assessment:
The recently enacted Biological Diversity Act (2002) has made the preparation of a "People's Biodiversity Register" (PBR) mandatory for village councils all over India. The India Local assessment provides a methodology for preparation of PBRs. Through model PBRs consistent with the MA framework, the following conclusions were derived for the changes taking place in ecosystems and their impacts on human livelihoods at the local scale in the assessment areas.

Land use changes and driving forces. In the Western Ghats, excessive levels of conversion of paddy fields to areca nut orchards has been undesirable, as this has increased irrigation water demands to an unsustainable level. The conversion of former village common lands used as grazing grounds to habitation or *Casuarina equisetifolia and Acacia* sp. plantations have led to a reduction in livestock holdings and a decline in organic manure resources. In Vidarbha, the availability of usufruct rights (Nistar rights) and awareness about it in recent years are important drivers for motivating people to think about resource management. Joint Forest Management initiated by the State Forest Department has also been an important driver and has led to several villages successfully implementing resource micro planning.

Soil and water. There is a widespread perception that a decline in the use of organic manure accompanied by an increase in the application of chemical fertilizers and insecticides has led to a serious loss in soil fertility as well as affected the quality of water and aquatic life. The traditional gravity flow irrigation method has been replaced by drips and sprinklers, which greatly reduce the water going back into streams or percolating to underground water tables—ultimately reducing the stock of underground water.

Agriculture and tree crops. The patterns and practices of agriculture, that is, the land under cultivation of seasonal / annual crops and tree crops have changed over time, thereby affecting ecosystem services.

Forests and forestry plantations. Original forests have disappeared due to deforestation in coastal villages in the Western Ghats of Karnataka. Overexploitation of forest resources has led to the opening up of the canopy, which coincided with the invasion of the exotic weed *Eupatonum odoratum (Chromolaena odorata)*. Forest plantations such as *Casuarina equisetifolia* and *Acacia auriculiformis* have largely come upon lands that were earlier maintained as community grazing lands.

Grasslands. People attribute the following causes for the degradation of grasslands and related ecosystem services in recent decades: (1) rapid depletion of common resources and (2) apathy of forest authorities towards cattle and fire.

Domestic animals. The introduction of high milk yielding breeds of domestic cattle in Karnataka villages has resulted in the loss of traditional breeds of cattle such as *Malnad Gidda*.

Fish. Fishing during the breeding season in the sea has resulted in the loss of fish diversity and density and also decline in the availability of fishes. Fishery resources are neither abundant nor diverse in other water bodies. Destructive fishing methods such as the use of dynamite and fish poisons have led to fish depletion.

Selected response options: In Koyyur village, the following responses have begun to be implemented:

- The forest department was compelled to form Village Forest Committees as a part of the JFPM so that people can participate collectively in natural resource management. The villagers are providing vital information to the Forest Department regarding timber smuggling.
- In Koyyur village, five farmers have come forward to dig the percolation pits in their plots.
- Three sacred groves have been identified and the process started for planting medicinal plants and endangered species.
- Morante (*Channa striatus*) fish breeding has been initiated.
- About 15 individuals were selected for developing kitchen herbal gardens and seed banks at the household level.

Scenarios: Three state-level and two national-level scenarios were developed. The state-level scenarios include:

Bioresource database. Indian states gear up to implement the National Biological Diversity Act, 2002. State-level documentation of bioresources in the state is undertaken to create a database. This will help to ensure better, more-informed decision-making. Such database building efforts will be taken up by states within a few years.

Strengthening the IPR regime and validation. States will be establishing a system of safeguarding people's knowledge related to bioresources and steps for adding value. There are examples which include initiatives taken by Government of India through the National Innovation Foundation. States will have such organizations at levels accessible to local people. Special efforts with the help of scientific institutions will be required to validate the knowledge. There has been an increasing demand to explore traditional knowledge for commercial use by blending it with modern technology. This will have to be done in parallel with knowledge documentation processes. Norms of benefit sharing need to be evolved. There is enough technical expertise available within the country in terms of information technology for safeguarding intellectual property.

Sustainability in strategies. States will have to take measures for devising strategies as per the Biological Diversity Act 2002, by declaring sites as biodiversity heritage sites, banning the extraction of particular species, etc. as suggested by documentation done at village level. These strategies will supplement the existing legal provisions like protected areas, etc.

The national-level scenarios developed by the project include the following:

Network of databases. As a follow up to National Biological Diversity Act, there will be a national database of bioresources in India. This process is likely to be initiated soon. By 2015 there could be networked information system available all over the country. The data mining from this system along with validation of knowledge will create opportunities for jobs all over the country.

Strengthen state and local functioning. Central government will have to strengthen various systems operating at state and local levels which include strategies for sustainable utilization, IPR protection and benefit sharing, and evolving systems of positive incentives.

For further information: http://144.16.65.194/hpg/cesmg/pbr_nov212002A.htm.

Funding: Ministry of Environment and Forests, Government of India ($40,000); Millennium Ecosystem Assessment ($10,000).

India Urban Resource (India Urban)

(See color version of locator map in Appendix A.)

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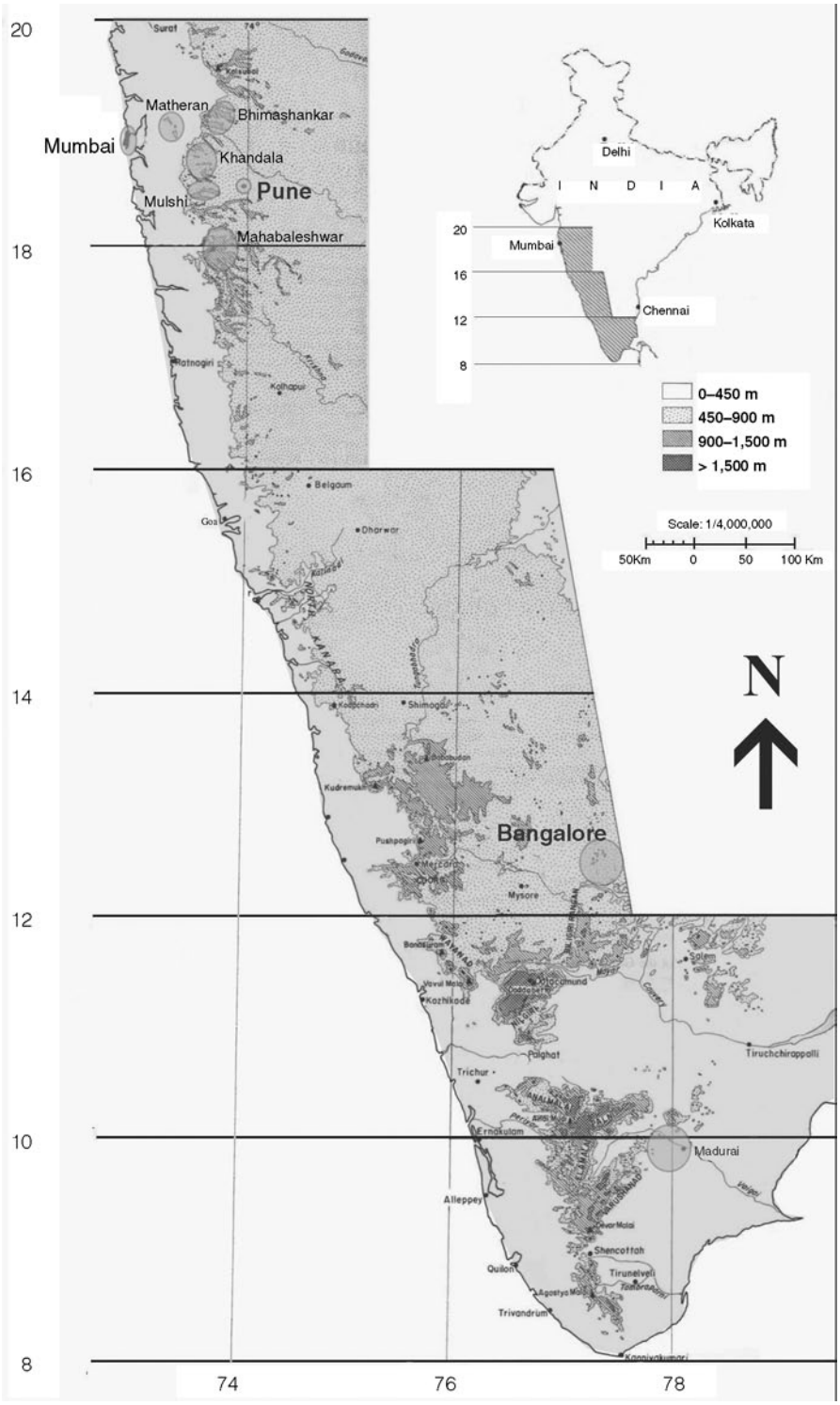
Introduction: The Indian Urban Resource Millennium Assessment by Naturalists is a nested national level assessment completed during 2000–04, with a focus on Pune, Bangalore, and Madurai cities at the local level. The focal issues are food, fuel, water, and health care; in addition, fiber, culture (including human well-being), biodiversity, climate, and waste recycling were studied opportunistically. The stakeholders consulted include traders, farmers, government officials, scientists, citizens, teachers, and students. Research and Action in Natural Wealth Administration (RANWA), an NGO, facilitated the India Urban assessment. Its partner Community Enterprise Forum of India



Indian Urban Resource Millennium Assessment

(CEFI), Madurai, focused on health care, and the Sustainable Rural Transformation (SuTRA) unit of the Indian Institute of Science (IISc) assessed fuel scenarios.

Methodology: Literature was surveyed during 2000–02 to document condition and trends. Response options and future scenarios were inferred from the proceedings of the 17 workshops regarding biodiversity, farming, fuel, water, and health care. These involved 3,000 stakeholders and were funded by various government agencies and private donors for their business planning. Data and projections include the past 50 and future 25 years, respectively, including negative feedback. Ecosystem product or process and response options were assessed with regard to input, process, output, and feedback over their ''life cycle.'' Experts from the stakeholder groups reviewed broadly the inferences drawn, when personally consulted.

Condition and trends: Urban population has grown two times and food consumption three times in the past five decades, and prices are low while farmers are paid poorly. Quality is deteriorating with growing chemical inputs, and reduced forest and pasture nutrients. Growing meat, milk, and sugar production, as well as 200 liters of daily direct water consumption (and pollution), has also reduced water resources and polluted the remaining surface and ground pools, bringing villagers in conflict. Fossil fuel imports have grown four times in the past 20 years with a five-fold rise in costs of private transport. Electricity and natural gas usage has grown three times, due to the use of electronic goods and fuelwood replacement, respectively. Air pollution—including approximately 0.5 kilograms of carbon per person per day—has exceeded safety levels by 20–40%. Health disorders per capita more than doubled despite growing medical facilities and costs, as 10% of citizens, especially children, have become obese, due to changes in diet, sedentary lifestyles, and a low diversity, low nutrition diet. Natural fiber for clothing, furnishing, packing, paper, etc., has been replaced mostly by synthetics, which generate daily 0.3 kilograms of waste per person, thus exhausting landfills around cities. The remaining 0.2 kilograms of waste per person is organic (kitchen waste and drainage), but not recycled, which is hampering farm, river, and costal productivity. Pollution has wiped out about 10% of fish species and overharvest another 5%, while narrow niche bird and plant species have suffered over 50% population loss, despite growth in exotic species. Culture of nature worship and celebration has eroded in the last three decades, as has its safety and savings orientation, using local handicrafts from biological products—grains, vegetables, milk, clothing, footwear, mats, furniture, gifts, etc.

Drivers: Direct endogenous drivers of declining ecosystem health and human well-being include: (1) land use changes such as reducing tree cover and open areas, while increasing built-up area density due to unplanned growth, hampering biodiversity, air, and water circulation, (2) rising private transport and air pollution, (3) consumerist lifestyle with enhanced (processed) food, mechanical tools, electricity, and water consumption (and wastage). Indirect exogenous drivers (mostly global/national) include (1) technological—mechanization or using handicrafts (2) economic—pricing, taxes, or concessions, (3) political—law and policy. Culture (education, media, religion) is a two-way driver.

Response options: Response options to gradually reduce pollution or (local) extinction, while generating rural employment (to reverse urban immigration) include (in increasing order of difficulty): (1) reviving traditional organic farming and diet (including diversity and balance); (2) low intensity handloom, recycled paper, and jute packing; (3) low transport using public modes and local biodiesel (from leguminous trees along avenues, wastelands, and farm bunds, to recycle carbon and nitrogen); (4) recycling kitchen waste and drainage to generate biogas and farm manure respectively; (5) rationing piped water supply to 50 liters, in addition to encouraging rainwater harvesting; (6) enhanced taxes on private vehicles/gadgets and high emission technology.

Scenarios: Two scenarios were developed.

Business-as-usual. The BAU techno-commercial scenario is a ''pleasure fuels violence'' story with the following components:

- National food imports (already begun with sugar and cotton) rise to 20% of the national demand in 2015, due to greater climatic uncertainty; reduced soil fertility and water availability; enhanced meat, milk product industry, and addictions (tea, coffee, tobacco).
- Fiber imports and fossil fuel imports as well as air and water pollution may double by 2025. Abrupt climate change, volcanic eruptions, flooding due to snow melting, earthquakes, and terrorism or war cutting fuel supplies, could occur. Biodiesel can hardly meet 5% of the excessive transport demand.
- Urban solid and water waste recycling may increase 20% and 30%, respectively, as a lucrative business, but increased concrete waste treatment could be difficult even with advances in nano-technology.
- Rising air, noise, water, and food pollution and growing assets could reduce human well-being as families and communities weaken. Crime, health problems, violence (including gender) and suicide grow. Food, water and fuel scarcity could trigger conflict.

Low External Input Sustainable Activities. This scenario is a ''contented local cultures'' community story, in which adaptive management is driven less by hi-tech education, profit, and pleasure motives, and more by traditional wisdom, ethical trading, and recycling jobs in cities and farm skills in villages. It employs an ''ecosystem approach'' (reuse, recycle and reduce or refuse) and the ''precautionary principle'' based on ''eco-religion,'' where uncertainty is minimized to climate alone. If realized, it can stabilize or reduce fiber and fossil fuel imports, while reducing mining and large dams. It can equitably provide 300 grams of diverse food and 50 liters of water daily, and three pairs of handloom clothes annually to all. Human well-being will be enhanced as personal creativity and choice grow along with local community interdependence and local governance.

Lessons: The following lessons were learned: (1) technology and economic growth require prior and periodic multidimensional and long-term environmental and cultural impact assessment; (2) science needs to be promoted as logical thinking for all people; and (3) lifestyle choices must be informed ones, for conserving natural and cultural diversity and stability. The results of the India Urban assessment will also be disseminated as children's stories.

Indonesia
Jakarta Bay and Bunaken ecosystems

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The assessment was conducted by Zainal Arifin, as chief scientist, with the assistance of members of the Jakarta Bay Working Group (for the Jakarta Bay site), and by Reihart Patt, chief scientist, with the assistance of the Bunaken National Park Management Council (for the Bunaken site). At the current stage, the exercise is focused on providing condition and trends of the ecosystem.

First site: The Greater Jakarta Bay Ecosystem (GJBE)
The period of assessment is 1992–2002. Scenarios are projected to 2020. Assessment completion is scheduled for end 2005.

GJBE consists of two distinct ecosystems: Jakarta Bay, which is strongly influenced by land-based activities, and Seribu island complex (*Kepulauan Seribu*), which is dominated by 110 small islands. The assessment of GJBE is intended to assist decision-makers at the national and local/regional levels in making decisions about managing the area. The main stakeholders in the area are national and local governments, as well as NGOs and private enterprises.

Marine biodiversity. GJBE is rich with marine biodiversity, especially in the National Marine Park of Kepulauan Seribu, including183 species of stony corals, 166 species of fishes, 101 species of seaweeds, 6 species of seagrasses, and 4 species of mangroves.

Food sources. Fish production from capture fisheries declined at an average of 11% annually during the last six years (1997–2002). Mariculture, especially green mussel and seaweed cultures, increasingly play a significant role in contributing to economic activities for local fishers.

Recreation. The Kepulauan Seribu National Park is one of the major attractions for tourist activities in the GJBE. The number of both local and foreign tourists continued to grow during the last 15 years, bringing benefits not only to the local government but also to local communities.

Pollution. Thirteen rivers flow into Jakarta Bay, which thus receives many pollutants. The inland area is considered the primary source of waste and pollutants, mainly due to untreated wastewater from the population of 20 million people of the Jakarta metropolitan areas and its industry.

Second site: The Bunaken Ecosystem
The period assessed is 1993–2002. Scenarios cover the period until 2020. Assessment completion is scheduled for end 2005.

The assessment, which covered the Bunaken National Park of North Sulawesi and its surrounding areas, is intended to assist decision-makers at the local level in making management decisions about the area. The main stakeholders are local government, NGOs, and private enterprises, which together established the Bunaken National Park Management Council.

Marine biodiversity. Bunaken has a high diversity of species of corals, fish, mollusks, algae and other marine biota, as well as mangroves. At least seven species of giant clam and endangered species of turtle and dugong can be found in the area.

Fisheries production. In the last several years, fisheries production from the area increased as a consequence of increasing numbers of fishers both in capture fisheries and mariculture (for example, seaweed). This increasing number of fisheries activities brings better income to the fishers.

Tourism. The number of tourists both domestic and foreign tended to increase in the last five years resulted in the growing of economic sector of the area. However, a concern has been raised in relation to the carrying capacity of the ecosystem for tourism activities, in particular for diving.

Funding: The first phase of the sub-global assessment (identifying condition and trends) was funded by GEF (seed funding) and supported by the Ministry of Environment (in-kind contribution). Therefore, fund-raising is needed in order to continue the next phase of the assessment (that is, preparing scenarios and responses).

For further information: The full report of the condition and trends of the Jakarta Bay and Bunaken ecosystems as the first phase of the sub-global assessment will be available at www.menlh.go.id.

Morocco, Saudi Arabia, Sinai: Arab Region Assessment

Overall project management:
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Location: Three sites have been selected from across the region to be the focal sites for this study:

- Assir National Park, Kingdom of Saudi Arabia; located in the Assir Mountains, which contain one of the most important ecological hotspots in the Arab region. Encompasses three main habitat types: sandy desert, high altitude habitats, and marine habitat of the Red Sea.
- Sinai Peninsula, Egypt; one of the main heritage sites of humanity, embracing a unique collection of sacred shrines and ecologically valuable landmarks. Includes the following ecosystems: desert, mountains, wetlands, coastal, agricultural, and marine.
- Tafilalt Oasis, Morocco; located in the Sahara in southeast Morocco, with an area of about 1,370 square kilometers. It contains date groves, palm trees, and small trading settlements.

Lead institutions: The UNEP Regional Office for West Asia is the lead organization to coordinate the regional assessment, in partnership with the following lead national institutions: Presidency of Meteorology and Protection of the Environment, Saudi Arabia; the Suez Canal University, Egypt; and the Moroccan National Observatory for the Environment.

Focal issues: The main goal of the project is to promote the adoption of integrated assessment approaches in the Arab region at the local, national, and regional levels. This will be accomplished by conducting a pilot study that will serve to develop the framework for a coordinated and integrated regional collaborative multiscale assessment effort. An integrated assessment approach will provide the information to decision-makers for designing a comprehensive and sustainable management plan for the environment.

Ecosystem services: The ecosystems to be addressed in this study are diverse, including desert, mountain, coastal, cultivated, freshwater, and rangeland ecosystems. These systems provide a wide range of services, including food, drinking water, water for agriculture and industry, medicinal services, aesthetic and recreational services, and other socioeconomically important products and services.

Project outputs: The outputs will include regional and site-specific assessment reports, web portals and national and regional information systems, capacity building strategies, regional conceptual framework and harmonized methodology, specialized in-depth modules of the training package, a series of workshops for both the producers and users, and an institutional network of partner institutions and expertise.

Key features of the assessment: The unique and highly vulnerable ecosystems of the Arab region are at serious risk from increasing human populations and their associated activities. The concept of this study is to select strategic sites of importance in the region that represent regional ecosystems and can be linked hierarchically with national and global ecosystems. The study is designed to provide the scientific information base to support decision-making and policy formulation in order to protect and promote sustainable management of the ecosystems in the selected sites and related areas. There is a movement to concentrate on increasingly decentralized governance in order to sustain ecosystem services at a local level. The study intends to provide the scientific information and knowledge for sound management of these resources.

Budget: The estimated funding for this project is $1,040,000. Some of the funding has already been secured while the various partners will raise the rest. Saudi Arabia pledged $400,000 for the study.

Northern Australian Floodplains, Australia

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Lead institution: Environmental Research Institute of the Supervising Scientist (ERISS). The Institute is a part of Environment Australia and a component of the Australian federal Department of Environment and Heritage.

Project objectives: To provide information on the floodplain and coastal ecosystems and their services of the tropical floodplains to the east of Darwin, Australia (including the Mary and Alligator rivers, which encompass the World Heritage and Ramsar Convention listed Kakadu National Park, and the Blythe-Liverpool rivers in Arnhem Land), noting information needs and analyses at multiple scales and taking into account multiple pressures on these ecosystems.

Methods:
The landscape analyses comprise sub-projects that address mapping at scales from the regional (biogeographical region; 1:500,000), catchment (East Alligator river: 1:250,000), sub-catchment (Magela creek and floodplain; 1:50,000) to individual reaches of streams (parts of Magela creek; 1:10,000). The Alligator Rivers Region covers about 2.8 million hectares and includes the entire catchments of two major rivers. The region will also be placed within a spatial biogeographical context, although analyses of major pressures will not be undertaken at this scale. Landscape analyses will be undertaken using appropriate imagery and all data contained within a GIS platform. The mapping approach will be based on the principles outlined in the Ramsar Convention Framework for Wetland Inventory and the Ramsar-endorsed Asian Wetland Inventory.

The analyses of pressures on floodplain and coastal ecosystems and their services will be undertaken using the Ramsar Convention framework for Wetland Risk Assessment. This encompasses an assessment of the extent and effect of the particular pressure(s) being considered, the extent of risk of adverse change occurring, and risk reduction and monitoring steps. In this manner, the three basics components of the MA process (condition/trends, scenarios, and responses) will be addressed. Information from across the region will be collated and assessed through this framework and, where necessary, complemented with information from specific research activities. Collating this information will involve collaboration with other research and governmental agencies responsible for particular sectors of the environment. The pressures that will initially be addressed include: feral animals and alien weeds (invasive alien species); infrastructure development and transport routes (including those linked with tourism and other developments); mining and milling activities; burning and fire regimes; and global climate change. Services that will be primarily addressed include provisioning services for local people, supporting services for biodiversity and ecosystem processes, and enriching services for the local indigenous and other resident populations.

The ecosystem services on the floodplains will be addressed through a framework based on that provided by the MA and adapted for local conditions. An initial framework has been developed after consultation; this will be expanded and information will added as it is collected and made available from stakeholders. This framework will sit alongside other ecological and economic investigations and developments within the regions. As these are being undertaken through different processes linked with local organizations, there is no intent to link them—the differences between the resource management structures and the likely outcomes provide comparative responses and options for management interventions.

Products: The primary purpose of the landscape-scale analyses is to provide information for managing the aquatic ecosystems within the region, noting that the responsibility for management decisions is shared between local landholders, governmental agencies, and resource managers. As the Institute does not directly manage ecosystems or their services it is necessary to present research/assessment outcomes in formats suitable for ready access by all stakeholders and decision-makers. The Institute already operates a transparent system for access to data and reports and specifically provides information to major stakeholders through formal and informal reporting procedures. This includes but is not limited to the Alligators Rivers Region Technical Committee. As a publicly-funded institution, all information collected by the Institute is made available. An annual report is presented and where possible information is published in the scientific literature. Copyright is retained in the public domain with publication in specific formats covered by non-exclusive permits.

Norway

(See color version of locator map in Appendix A.)

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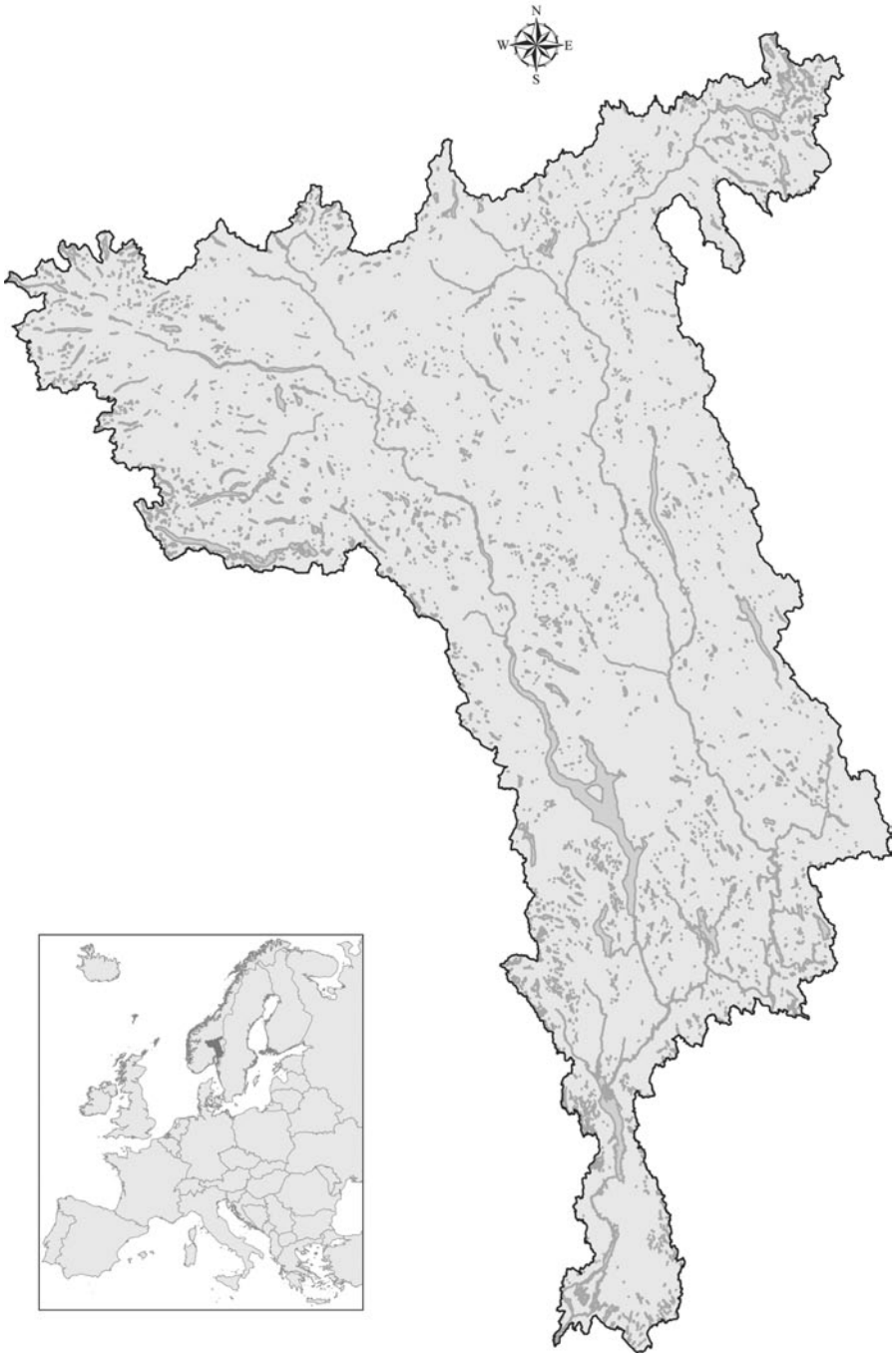
Project team and institutions: The pilot study was conducted by Signe Nybø of the Directorate for Nature Management and Odd Terje Sandlund of the Norwegian Institute for Nature Research. The scenario project on Østfold was conducted by Bjørn Åge Tømmerås and Hanne Svarstad of the Norwegian Institute for Nature Research.

Time period: Conditions and trends was assessed from 1900–2000, with time scales differing among services investigated. The scenarios were projected until 2025. The conditions and trends assessment was completed February 2002, while the scenario project was completed in September 2004.

Intended audience: national and regional decision-makers.



Glomma and Lägen River Basins

Summary of findings:
The pilot study prepared the decision for undertaking a full-scale study. The pilot study consisted of three main parts: (1) proposals for the content and organization of a full scale study, (2) a survey of Norway's natural environment and its ecosystem services, and (3) a case study from the Glomma river basin. Glomma is the largest river in Norway.

The pilot study concluded that Norway both had the data and the capacity to do the full-scale study, and also that several sectors had an interest in doing it. However, the full-scale study never got funded; reported here are the results of parts 2 and 3.

Survey of Norway's natural environment and ecosystem services. This part of the pilot study comprises a simplified analysis of the condition of, and trends within, values and services associated with Norway's natural environment. The study compares the current status with the situation as it was about a hundred years ago.

The Glomma river basin study. The Glomma case study demonstrates how data series from diverse social sectors and activities can be used to analyze the way in which the extraction of products and services from ecosystems simultaneously depends upon, and exerts influence on, the condition of the ecosystems. The demands of one sector for extraction of services can influence the potential for extraction desired by other sectors. The Glomma river basin exemplifies many of the opposing interests, conflicts and necessary compromises faced by those involved in nature management. Some examples are:

- The construction of infrastructure leads to the fragmentation of the landscape. We know this has a negative effect on species such as wild reindeer, but we lack much information on the other effects of such fragmentation. In the Glomma river basin, the areas south of the line Trysil—Elverum—Hamar—Gjøvik are today devoid of encroachment-free areas, and in the areas north of this line the encroachment-free areas largely coincide with existing or planned conservation areas.
- The areas of old-growth forest have diminished, while at the same time the forests contain a larger volume of timber and have a different structure than they had fifty years ago. This efficient management of forest resources aimed at lumber production has probably led to the loss of biological diversity at the species or ecosystem level.
- Economic and political conditions at national and international levels promote changes in farming methods. Larger areas of uninterrupted fields and fewer field boundaries and groves provide for more efficient food production. Changes in the cultural landscape have consequences for tourism and outdoor pursuits in terms of experience and enjoyment value. The homogenization of the landscape can be detrimental to the tourist industry.
- Along the coast, conflicts of interest continually arise between the construction of holiday cottages or other infrastructure and the public's rights of access to land and sea. This problem also arises along the coast near the mouth of the Glomma.
- The watercourse today supplies diverse services and products such as hydro-electricity, supply of water to households and irrigation, cleansing of drainage water and recreation. Future conflict between different user interests on the watercourse will probably occur in different combinations in each individual case.

Scenarios: Three scenarios were developed for the Glomma river outlets. The *bush encroachment scenario* and the *urban growth scenario* are trend scenarios in which two present tendencies are imagined as being dominant toward the year 2025. The third scenario provides a contrast in which both of the two sets of trends have been avoided by various political actions. The study was carried out as a cross-disciplinary collaboration based on ecology and sociology.

Funding: The pilot study was funded by the Ministry of Environment of Norway, while the scenario project was funded by the Nordic Council of Ministers.

For further information: The two reports may be found at www.maweb.org.

Papua New Guinea (PNG)

Coastal, small island, and coral reef ecosystems

(See color version of locator map in Appendix A.)

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Project team and institutions: This assessment is undertaken by a team of scientists coordinated by staff at the Australian National University and the University of Papua New Guinea. The first phase of the assessment (due for completion in 2005) is a nationwide survey of the relationship between coastal communities and coastal ecosystems, with a number of local-level case studies of this relationship. The second phase (due for completion in 2007) will focus on community-based assessments in one of the case study areas. This second phase is an integral component of the Milne Bay Community-Based Coastal and Marine Conservation Project (MBCP), which is being implemented by UNDP and executed by Conservation International. This project has its own Steering Committee with representation from a variety of stakeholders.

Time period: The period assessed is 1975–2000. Scenarios are projected until 2020. The assessment is scheduled for completion in March 2007.

Intended audience: national and provincial decision-makers, conservation organizations, university students, and local communities.

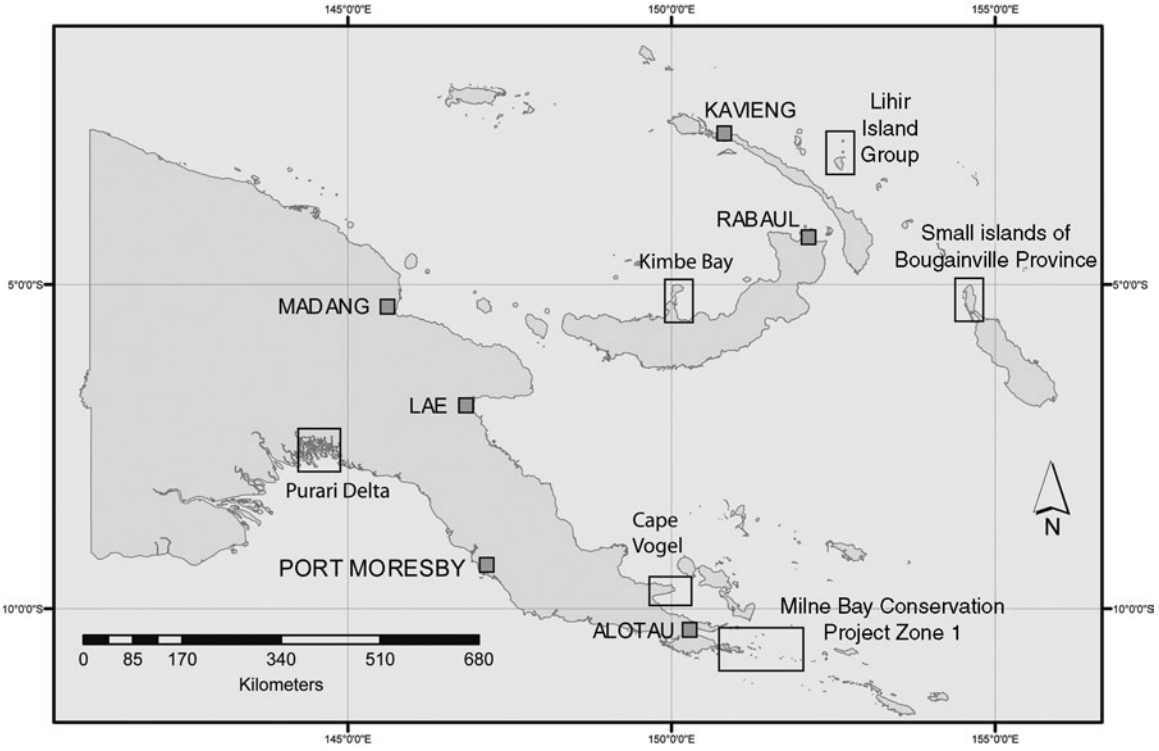
Focus: The main focus of this assessment is population pressure as a driver of ecosystem change in coastal and small island communities. Other significant drivers of change in PNG's coastal ecosystems are climate change, tectonic disturbances, the industrial exploitation of inshore marine resources, and the discharge of industrial and domestic waste material. The areas selected for local-level case studies in the first phase of the assessment are intended to reflect the extent of local variation in the relative significance of different drivers.

Within the coastal zone, both terrestrial and marine communities are assessed. Terrestrial communities include ''uncultivated'' forest (including sago groves); cultivated land (including bush fallows and orchards); other ''natural'' communities (such as grasslands and wetlands); and towns, villages, and other ''built-up environments.'' Marine communities include mangrove swamps; coral reefs; seagrass beds; and unvegetated bottoms. At the national scale, information about the supply of ecosystem services is primarily arranged by reference to indigenous food-cropping systems, which are treated as the core component of local resource management regimes in rural areas. Human well-being is measured by cash income, access to government services, and indicators of health, nutrition, and life expectancy.

The two scales of analysis and interpretation in the first phase of the assessment are the national and local scales, where each of the local case studies encompasses an area roughly equivalent in size and population to that of a single local level government in PNG. A preliminary assessment of the relationship between people and ecosystems in the area designated as ''Zone 1'' by the MBCP will count as one of five local case studies documented in the report of the first phase.

In the second phase, the national and local scales will be replaced by the provincial and community scales, because the assessment will focus on the coastal ecosystems of Milne Bay Province (one of 19 provinces in PNG) and on a number of coastal and small island communities within Zone 1. This phase is known as the Small Islands in Peril Program (SMIP) because of the preponderance of small island communities in this area.

As a sub-global assessment within the MA process, the Milne Bay SMIP has four objectives—to:



Papua New Guinea Coastal, Small Island, and Coral Reef Ecosystems

- build a credible and feasible framework for the collection, analysis, and synthesis of ecosystem-wide data for decision-making at the level of the local community and the province as a whole;
- test this framework in community-based assessments of ecosystem services in the area(s) of interest to the MBCP;
- address decision-making information needs at the provincial level by means of scientific analysis, scenario construction, and policy advice; and
- build capacity to undertake integrated assessments of the relationship between ecosystems and socioeconomic systems at local, provincial, and national scales.

For further information: To learn more about the design, progress, and outputs of the PNG assessment, see www.maweb.org.

Funding: The MA provided financial support for the first phase of this assessment, including production and dissemination of the national report. The second phase is funded by UNDP as part of the co-financing of a grant from the Global Environment Facility.

Laguna Lake Basin, Philippines

(See color version of locator map in Appendix A.)

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The Philippines

Project team and institutions: The assessment is conducted by a panel of 25 scientists from the University of the Philippines (UP), Laguna Lake Development Authority (LLDA), Department of Science and Technology (DOST), Department of Environment and Natural Resources (DENR), Madecor Environmental Management System, Inc. (MEMSI), the SEAMEO Regional Center for Graduate Study and Research in Agriculture (SEARCA), and Haribon Foundation. They are headed by the Coordinating Lead Authors, namely, Rodel D. Lasco, Ma. Victoria O. Espaldon, Adelina Santos-Borja, Macrina Zafaralla, Leonardo Liongson, Adelaida Palma, Benito Vergara, and Edwino Fernando. The advisory committee is composed of heads and representatives of various research and development institutions and an NGO; its members are DENR Secretary Elisea G. Gozun, Victor Ella, LLDA General Manager Casimiro Ynares III, Laguna Governor Teresita Lazaro, Rizal Governor Rebecca Ynares, Ramon Razal, Enrique Pacardo, Patricio Faylon, Rafael Guerrero, and Emerson Jacinto.

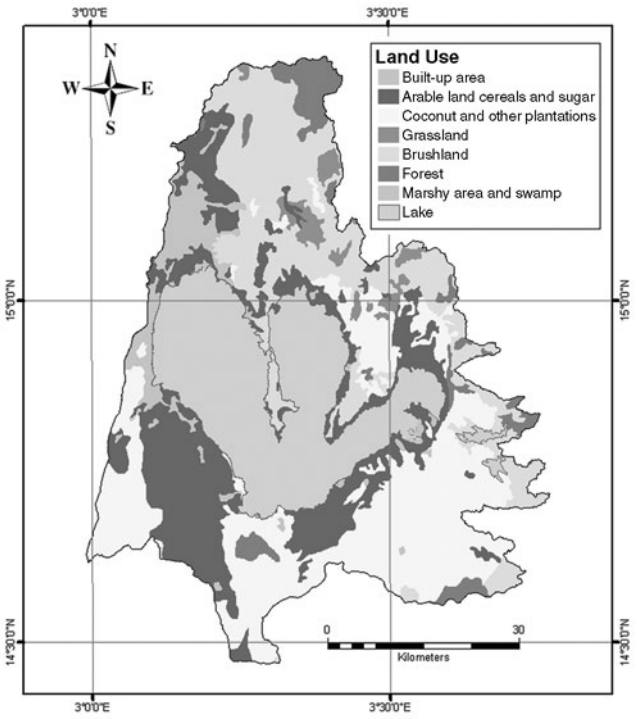
Time period: The period assessed is 1990–2000. Scenarios are projected to 2050. Assessment completion planned for mid-2005.

Intended audience: decision-makers at various scales: farm/village, basin/watershed, and national, especially the LLDA and DENR.

Ecosystem services assessed:
The following ecosystem services were assessed: water resources, fish resources, rice, biodiversity, and climate change in the Laguna Lake Basin. The scale of the assessment was nested from the local (farm/village) to the basin/watershed to the national policy implications of the findings. Major stakeholders include: farmers and fisherfolks, depending on the services provided by the lake, local government units, LLDA and DENR.

Water resources. The biological and chemical analyses of the water coming from the lake and its tributary rivers showed that many water quality parameters have already either exceeded or fallen below the criteria for Class "C" (suitable for fishery) waters, indicating the worsening condition of the lake. This has affected the productivity of the lake, particularly fish production. Hence, Laguna de Bay is in need of rehabilitation, of restoration to a past state that is more acceptable.

Fish resources. The fisheries of Laguna de Bay have been affected by human, industrial, and environmental factors which resulted in a 64% decline in production levels between 1980 and 1996. Species diversity has also significantly declined, with exotic aquaculture species dominating the catch. Although the number of fishermen operating in the lake has been reduced by 50.4%, they have remained in marginalized condition and there is a need for a viable alternative/supplemental livelihood.



Laguna Lake Basin, Philippines

Rice. The Laguna de Bay has a shoreland area of around 13,900 hectares, of which around 5,700 hectares are planted to rice. Rice production in this area can supply 14% of the total rice requirement in the Laguna de Bay region. However, this service provided by the basin is affected by a multitude of factors, such as the decrease in water level in the lake, quality of rice culture, construction of circumferential road, and land conversion. Meanwhile, due to the economic and social benefits gained from the shoreland, population growth and increasing and changing demands in resources and development activities pose a threat to the basin. Hence, institutional arrangements have been set up by LLDA on the use of shoreland and water on the lake.

Biodiversity. Six specific areas in the watershed are included as biodiversity priority areas in the Philippines due to the critical state of wildlife in these areas. The imbalance brought by the extirpation and decline of different species in the basin, as well as the introduction of alien species, has brought problems in agricultural production, particularly with some species causing damage to crops while others are considered nuisance animals in homes and public buildings. Introduction of alien species, chemical pollution, overextraction, and reduction of habitats of the wild flora and fauna pose a continuing threat to the indigenous biodiversity of the lake basin.

Climate change and the Laguna Lake Basin. Forest lands in the Laguna Lake Basin could help mitigate climate change through (1) the protection of existing forests with their carbon stocks (19,000 hectares storing about 2,850 kilotons of carbon) and (2) reforestation and rehabilitation of open and degraded lands (54,000 hectares with a potential carbon sequestration rate of 1,338 kilotons of carbon per year). Although climate change is not yet explicitly integrated in planning and implementation activities in the basin, many activities are being undertaken that indirectly contribute to the mitigation of climate change.

Funding: This work is funded by the MA and DENR.

Portugal

(See color version of locator map in Appendix A.)

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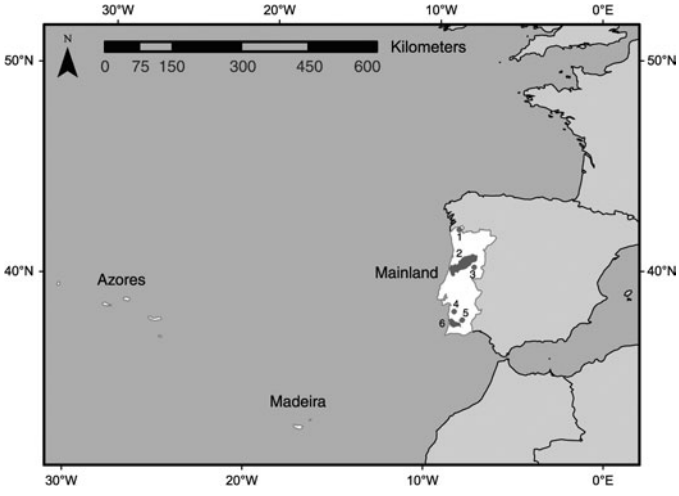
Organization: The assessment is led by Henrique M. Pereira, Tiago Domingos, and Luis Vicente. The coordinating institution is the Center for Environmental Biology of the Faculty of Sciences of the University of Lisbon. The scientific team is composed by 40 scientists from over 10 universities, research institutions and government agencies. The intended audience for the assessment is national and local decision-makers. The board of users has ten members representing government agencies, non-governmental organizations and the private sector. The advisory board is composed by seven members, including scientists and decision-makers and is chaired by Isabel Guerra (Ministry of Public Works, Transportation and Housing).

Time period: The period assessed was ecosystem service dependent, but aiming at 1964 to 2004. Scenarios are projected until 2050. The assessment started in May 2003, and the main report will be published in late 2005.

Study area: Portugal (Ocean—326,362 km^2; land—91,947 km^2), population *circa* 10 million. Analyzed MA system categories: marine, islands, coastal, inland waters, forest, mountain, cultivated, and urban. Additionally, the ''montado'' is analyzed. This is a woodland, predominantly with cork- and holm-oaks, managed for silviculture, agriculture, and animal husbandry. It occurs mostly in the south, which is a dryland area. There are two case studies at the basin scale and four at the local scale, sampling different systems.

Major findings:

Drivers. The most important drivers of ecosystem change in Portugal are: fire regime, land use changes (including abandonment of agricultural fields, afforestation, and urban sprawl), the European Union's Common Agricultural Policy, global markets, and economic growth. Other important drivers include environmental legislation, social attitudes toward the environment, tourism, demography, and exotic species. In some instances, these drivers interact synergistically. For instance, economic growth has led to increasing labor costs which, in association with reduced agricultural revenues, have led to the abandonment of agriculture, facilitating the establishment of shrubs, and hence increasing the frequency and intensity of fires.



Portugal

Overall analysis of the condition of the systems. Condition of ecosystem services is very heterogeneous across systems, with inland waters presenting more problems than any other system. Curiously, the dryland ''montado'' appears to be doing relatively well. The size of some systems is changing with forest and shrub land expansion and the partial abandonment of cultivated fields. The estimated economic value of ecosystem services from the forest is at least 900 million Euros per year, with at least 20% of this value coming from nonmarketed services such as soil and flood protection. Furthermore, 5% of the total employment is associated with the forest sector.

Food production. During the second half of the twentieth century, food production in the cultivated systems grew much slower than national food demand. Use of fertilizers and pesticides is generally low, when compared with other EU countries. Nevertheless, there is excessive fertilizer use in some places, causing contamination of underground water. Other localized problems include soil erosion due to poor agricultural practices and loss of fertile soil to urban sprawl and other land uses. Fish landings from the ocean and the coast have decreased over the last decade, but at the same time, oceanic fish stocks have improved and the majority of oceanic species are above the precautionary biomass threshold. Nevertheless, some oceanic species are overexploited and, in a few cases, even with strong regulation, recovery will be very difficult. Coastal fisheries are doing worse than oceanic fisheries, partially because of pollution and eutrophication. In inland waters, there has been an increase in food production due to aquaculture but the sustainability of that production has been decreasing due to its impacts on water quality.

Freshwater provisioning. About 75% of water consumption is associated with agricultural activity and about half of the water comes from underground sources. Despite some localized problems (including highly variable intra- and inter-annual runoff in the south), there are no critical problems of supply and demand of water in Portugal. However, there are serious problems with water quality. Several aquifers in the cultivated systems (particularly those in the central coastal region) have problems with nitrate pollution and saline intrusion. Moreover, several rivers are heavily polluted from industrial, farming, and domestic activities, with eutrophication occurring in some basins. Finally, despite the increase in total forest area over the last decades, the capacity of forests to provision freshwater has not improved significantly due to the increase in fire frequency and because the majority of the forest area increase is with eucalyptus plantations, which are worse than oak or pine forest for water provisioning.

Timber and cork. Annual fellings for wood supply are about the same amount as the net annual increment in forests with the same main function. However, better management could both improve annual increments by more than 20% and the sustainability of the production in terms of fertilizer use, soil erosion, and nutrient depletion. The dryland ''montado'' produces more than 50% of world cork, a process that has high ecological sustainability.

Biodiversity. Broadly speaking there is a spatial overlap between terrestrial biodiversity and human populations in Portugal: areas with more species are also under the highest pressure for development. However, most sites with high irreplaceability of biodiversity are protected under the Natura 2000 network. Still, biodiversity is declining in most sys-

tems, both in populations of indicator species such as top predators and in area of rare or vulnerable habitats. The worst situations are found in forest, inland water systems, coastal areas and urban areas: in northern and central Portugal only a tiny proportion of forest is native oak forest, instead monocultures of eucalyptus and pine dominate; inland water systems have suffered from dam construction, pollution and eutrophication; in coastal areas the pressure from urban development and tourism has led to the loss of wetlands and other habitats; in urban areas lack of green parks and poor urban planning is the main problem. Some marine species such as seabirds and mammals have decreased their range or population size, but surveys of ocean fish species do not show negative trends. Some cultivated systems such as cereal pseudo-steppes and slough fields are particularly important for biodiversity but their maintenance is threatened due to agricultural abandonment. On the other hand, agricultural intensification in some other areas has led to landscape homogenization and loss of biological diversity including loss of domestic races.

Soil protection and water cycle regulation. Critical ecological problems with soil protection and water cycle regulation services occur in the urban system (poor urban planning) and in the coastal areas (loss of wetlands and infrastructure development near cliffs). In some cultivated areas in the south of Portugal, cultivation of cereals with excessive tillage in inadequate soils and the decreasing use of crop rotation has led to soil degradation, recovery being particularly difficult in that dryland area. The forest system is affected by fire frequency, which causes soil loss during rainfall, deterioration of water quality downstream and increased run-off.

Climate regulation. Current knowledge of the role of Portuguese forests in carbon sequestration is limited. An (under)estimate of Net Biome Productivity is about 1.52 million tons of carbon per year, which accounts for 7% of carbon emissions in 2000. While carbon sequestration capacity has been improving due to the increase in total forest area, this improvement is hampered by increases in fire frequency and intensity.

Recreation. In 2000, total income from tourism represented about 8% of GDP. The vast majority is associated with mass tourism in coastal areas, where signs of saturation and even deterioration of recreation quality are appearing. Hunting is one the most important recreational services in forest, cultivated and mountain systems, with an estimated annual economic value of 60 million Euros. The recent creation of associative hunting zones and tourism hunting zones implementing a user-pays philosophy and the assurance of no-hunting rights to land owners may improve the condition of this service. But concerns have been raised about predator control in these zones. There are about 2 million non-hunting visit-days per year to forest and mountain areas. Furthermore, there is now an increase in demand for rural tourism in areas with traditional agricultural practices. Finally, dam construction in inland waters has provided new opportunities for recreation, including sailing and bathing areas.

Scenarios: The assessment team started by trying to develop its own scenarios, but it turned out that these overlapped partially with the global MA scenarios. So a decision was made to build on the work already done for the MA global scenarios, and adapt those scenarios to the Portugal scale. This process is ongoing but it is already clear that different scenarios have very different outcomes in terms of the evolution of ecosystem services and that the most important drivers at the Portugal scale may differ from the drivers at the global scale. Also, scenarios bring out trade-offs between different ecosystem services.

Responses: One of the major responses analyzed was the acquisition of farms by a national scale environmental NGO in a specific "hot spot" area for hosting biodiversity, the cereal pseudo-steppe, responding to land use changes driven by the European Union's Common Agricultural Policy and the pressure to create eucalyptus plantations. This multi-scale intervention of an environmental NGO has been very useful. The technical capacity and intervention influence of the NGO, owing to its national scale, has been applied at the local level. At the same time, this experience has had feedback on its intervention at the national scale. However, the strong focus of the NGO on biodiversity conservation has led to a low performance with respect to soil conservation. Managing this trade-off is still an open problem.

Ecosystem services and human well-being in the mountain community of Sistelo: From the perspective of the Sistelo community, some of the local criteria for well-being are closely related to local ecosystem services but the majority are not. People recognize many services provided by ecosystems, particularly provisioning services, but also cultural and regulating services. Some components of well-being such as material well-being have been improving over the last decades, while some ecosystem services such as food production have been declining. This disconnect between well-being and ecosystem services at the local scale is a consequence of the increased buying power that individuals now have, which allows individuals to substitute local ecosystem services for goods from the outside.

For further information:

Web site: www.ecossistemas.org

Pereira, H.M., T. Domingos, and L. Vicente (eds.), 2003: *User Needs and Response Options Report. Portugal Millennium Ecosystem Assessment.* Available online at ecossistemas.org.

Pereira, H.M., T. Domingos, and L. Vicente, 2004: *State of the Assessment Report. Portugal Millennium Ecosystem Assessment.* Available online at ecossistemas.org.

Funding: The Portugal assessment received a $32,500 grant from the MA. Other grants and support totaling about $6,000 came from: Caixa Geral de Depósitos, Universidade de Coimbra, Universidade Católica Portuguesa, and Caminhos de Ferro Portugueses. In-kind contributions from the researchers' institutions and from Fundação da Ciência e Tecnologia totaled about $100,000.

SAfMA Regional Scale Assessment (SAfMA Regional)

A component of the Southern African Millennium Ecosystem Assessment

(See color version of locator map in Appendix A.)

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Time period: The period assessed was 1960–2000. Scenarios were projected to 2030. The assessment was completed in June 2004.

Intended audience: National and regional decision-makers.

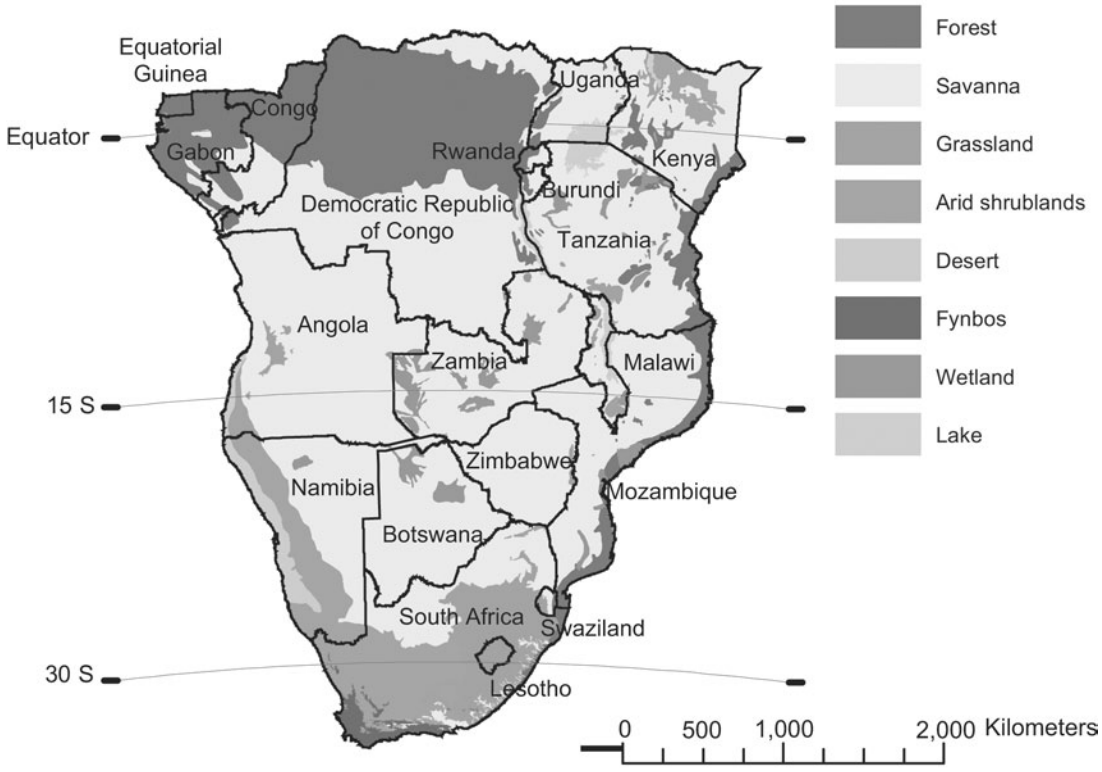
Major findings:
By standard measures of well-being, the countries of the southern African region are on average in the bottom quarter of the world ranking, and even the best-off countries are in the bottom half. The total population of the study region in 2001 was 275 million, increasing at 2.2% per annum. One third of the population is urban, and this fraction is rising rapidly.

Fresh water. Southern Africa, broadly speaking, has a water-scarce south and a water-rich north. There is high potential for conflict over the many shared water basins, both between countries and between sectors. A key policy response in the critically dry countries has been to make water allocation more market-related, after first protecting the minimum needs of people and riparian ecosystems.

Food. The region as a whole produces nearly enough carbohydrate crops to meet the minimum needs of its population, but due to distribution inequities, up to 25% of the population is undernourished. The situation regarding protein nutrition is serious. The protein supply for people living north of the Zambezi river is below the minimum daily requirement, and declining. There is little scope for increased off-take from natural fisheries, half of which are already overfished. There is technical opportunity for greater protein off-take from livestock. Currently, a significant part of the unsatisfied nutritional needs of the region are probably derived from natural ecosystems.

Biomass fuel. Three quarters of energy for household cooking and heating in the region is supplied by wood and charcoal. There are wood fuel supply shortages in a number of clearly delineated areas, but overall wood growth is adequate for a sustainable harvest. Use of biomass fuels has climate change mitigation advantages but, if burned under poorly ventilated conditions, is the major cause of poor indoor air quality and leads to severe health problems.

Air quality. Domestic wood burning, wild fires, and industry currently contribute almost equal amounts to regional air pollution, which due to the unique circulation pattern over southern Africa, often reaches alarming levels during the winter months. Emission increases in the future will necessitate a collective, multinational approach to managing air quality.



Southern African Regional Assessment. This covered 19 countries in mainland Africa south of the equator, and eight major biome types. (Scholes and Biggs 2004)

Biodiversity. Southern Africa has a disproportionately high fraction of global biodiversity. In most instances it is nearly intact, both inside and outside protected areas, but certain groups of species, and certain unique locations, are endangered. The most highly transformed ecosystem type is grassland. The current forested area (including woodlands) is estimated to be 4 to 5 million square kilometers, depending on the forest definition adopted. Using a new index developed for the study, it is calculated that 85% of the pre-colonial biodiversity is intact in the region. The natural features of the region form the basis of a major nature-based tourism sector, already contributing significantly to the regional economy, and growing three times faster than agriculture or forestry.

Scenarios. The study explored the consequences to ecosystem services of two political and economic scenarios. One projects forward the current trend of slow economic growth, marginalization from the global economy, and weak governance. The other assumes that efforts to put the region onto a different development pathway through stronger governance are successful, leading to higher economic growth rates and greater industrialization and infrastructural development. In the first scenario, direct dependence on ecosystem services, especially in rural areas, overwhelms local supply in many places, leading to accelerated degradation and transformation. In the second, limited water supply and deteriorating air and water quality constrain the improvements in quality of life.

Synthesis. Overall, there is a remarkable spatial congruence between areas where ecosystem services are under pressure, and locations of recent conflict. This interaction probably works both ways: in some cases, the conflict may be a result of the shortage of resources; in others, the resultant breakdown of authority may be the cause of the resource exploitation. At least four of the eight Millennium Development Goals will not be met in the region unless attention is given to stabilizing ecosystem services.

For further information: See Scholes, R.J., and R. Biggs (eds.), 2004: *Ecosystem Services in Southern Africa: A Regional Assessment*. CSIR, Pretoria, South Africa. 75 pp. Available online at www.maweb.org.

Funding: This work was funded by the MA, including a grant from Norway, administered by UNEP.

SAfMA Gariep Basin Assessment (SAfMA Gariep)
A component of the Southern African Millennium Ecosystem Assessment

(See color version of locator map in Appendix A.)

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Time period: The period assessed was 1993–2003. Scenarios were projected to 2030. The assessment was completed May 2004.

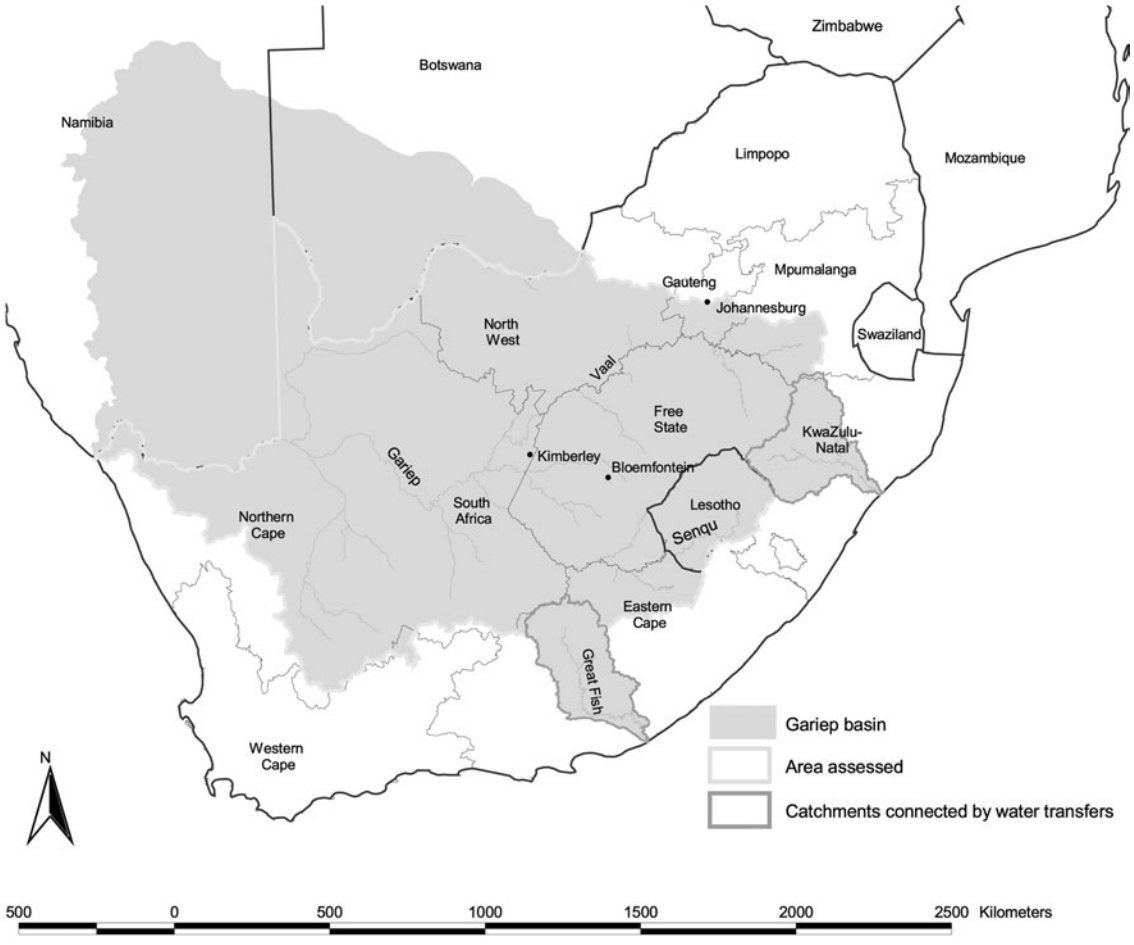
Intended audience: national and provincial level decision-makers, research institutions.

Issues addressed:

Fresh water. The Gariep is a water-scarce basin, with runoff distributed disproportionately across the landscape. It is the region's most regulated basin, with large dams and extensive transfer schemes, most notably from the Lesotho highlands to the growing urban area of Gauteng. Transformation has altered biodiversity, and water quality problems threaten domestic and irrigation supplies. The water sector is currently being decentralized and is initiating pricing policies to recover the full costs of using water. The National Water Act of 1998 prioritizes allocation of water to ecosystems and basic human needs, but ecological requirements have yet to be defined, while infrastructure to deliver water is lacking in some rural areas, and some households cannot afford to pay for water services.

Food. Food production in the Gariep contributes to livelihoods, markets, raw materials foreign exchange, and surplus or ''savings.'' Agriculture is a source of water and air pollution and mismanagement has resulted in significant land degradation. Fertilizers and pesticides may have negative effects on health, while genetically modified organisms are controversial but offer promise for boosting agricultural productivity. Food security is being compromised by declining household incomes, changes in land tenure and market access, and HIV/AIDS. Subsistence farming, food gardens, wild foods, game farming, and bushmeat are important food sources not usually reflected on national balance sheets.

Energy services. In the rural areas and the informal economic sector, biofuels remain an important energy source, while electricity or fossil



Location of the Gariep Basin, International Boundaries, South African Provincial Boundaries, Major Rivers, and Major Cities. Note that the actual Gariep basin extends beyond the area assessed. (Bohensky et al. 2004)

alternatives supply urban households. About 70% of South Africa is electrified, dropping to 50% in rural areas and 3% in Lesotho. Local fuelwood depletion occurs in some rural areas, while burning of coal, though abundant, produces high carbon dioxide and sulfur dioxide emissions, affecting air quality and contributing to greenhouse gas emissions. Potential for solar power is very high in the Gariep, but investment in alternative energy technologies remains limited.

Mineral services. Minerals are of special interest in the Gariep basin because of their contribution to the economy and employment. Mineral extraction creates excessive ecological disturbance which interferes with ecosystem function and biodiversity, and by-products of mining affect air and especially groundwater quality. Mining legislation passed in recent years has required the sector to implement more sustainable and equitable practices, though in general, the largest benefits of mineral services rarely accrue to those who bear the cost of mining's externalities.

Cultural services. Cultural services exist across the landscape but may be highly localized, such as sacred pools and forests, taboos, rituals, religion, language, and ecological knowledge systems. Cultural services in some areas are threatened by land use pressures, increasing urban contact, modernization, and influences of other cultures. Some cultural services in the Gariep basin are recognized formally by South Africa's Natural Heritage Act and the World Heritage Convention.

Biodiversity. The Gariep basin is less well protected than South Africa on average, despite the occurrence of two important biodiversity areas—the Succulent Karoo and Drakensberg highlands—within its boundaries. About 84% of the Gariep basin remains in its natural state, while the rest is transformed mostly by cultivation (93%), followed by urbanization (4%) and overgrazing and fuel wood removal (4%). The Grasslands, being nearly 30% transformed, are the most threatened biome and most poorly protected. While overall protected areas are increasing and several large transboundary parks have been or will soon be established, conservation in South Africa is moving away from a sole focus on protected areas and is embracing other techniques, such as economic incentives for promoting conservation on private or communal land.

For further information: The full study is published as Bohensky, E., B. Reyers, A.S. van Jaarsveld, and C. Fabricius (eds.), 2004: *Ecosystem Services in the Gariep Basin: A Basin-Scale Component of the Southern African Millennium Ecosystem Assessment (SAfMA),* SUN Press, Stellenbosch, South Africa, 152 pp. Available at www.maweb.org

Funding: This work was funded by the MA, including a grant from Norway, administered by UNEP.

Kristianstad Wetlands, Sweden (Sweden KW)

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Time period: Condition and trend assessment applies to the years 1989–2003. Scenarios are under development. The project timeframe is 2001–2005.

Area description: Kristianstad Wetlands is a semi-urban area of high biological and cultural-historical values in southeastern Sweden. It was designated to have international importance by the Ramsar Convention on Wetlands in 1974, and is currently being evaluated to become a UNESCO Man and the Biosphere Reserve. KW covers 1,100 square kilometers of the Helgeå River catchment area and the coastal regions of Hanö Bay within the municipality of Kristianstad. The whole catchment of the river is 4,749 square kilometers. KW includes Sweden's largest areas of flooded meadows used for grazing and hay-making. Many of the unique values of the area are associated with these social-ecological systems, which depend on both the proliferation of grazing and hay-making, and the annual flooding of Helgeå River. The wetland areas are directly connected to Kristianstad, a city of 28,600 inhabitants. The whole municipality has 75,000 inhabitants.

Methods and approaches:
This assessment was carried out in an area where the ecosystems have been managed in an adaptive collaborative process since 1989, by the Ecomuseum Kristanstad Vattenrike (EKW) and local steward associations. The assessment area was chosen because Kristianstad Wetlands appears to be an example of a successful response to a perceived decline in ecosystem services. The response consists of formulation and implementation of the ecosystem management approach, including involvement of many different stakeholder groups (local steward associations), linking scales, combining knowledge systems, and using ecosystem services while maintaining them. The assessment identified three types of knowledge relevant to ecosystem services: (1) ecological knowledge, (2) technology and knowledge of management practices, and (3) knowledge of social processes behind management practices. Ecological knowledge involves knowledge of flora and fauna and their diversity as well as ecological processes and functions at various temporal and spatial scales and how these processes are linked across scales. Our aim was to draw lessons from KW that could be applied in other areas. In addition, the assessment process would strengthen the on-going management by providing useful frameworks such as resilience theory and the MA conceptual framework. Understanding social factors such as learning, trust building, sense making, conflict resolution, as well as navigating rules, incentives, and funding are crucial for increasing the capacity of managing ecosystem services in a sustainable fashion.

Information was collected through literature review, including scientific reports and other reports such as vegetation surveys, species inventories, land use maps, historical records, protocols, and annual reports. We also conducted social-ecological inventories and semi-structured interviews with key informants.

Key findings:
Social mechanisms behind transformation toward ecosystem management. In KW, the self-organizing process was triggered by the perceived threats to the area's cultural and ecological values among people of various local steward associations and local government. The threats challenged the generation of ecosystem services in the area. We show how one individual, a key leader, played an instrumental role in directing change and transforming governance. The transformation involved three phases: (1) preparing the system for change, (2) using a window of opportunity, and (3) building social-ecological resilience of the new desired state. The local policy entrepreneur initiated and created trust-building dialogue and mobilized social networks with actors across scales, and started processes for coordinating people, information flows and on-going activities, and for compiling and generating knowledge, understanding, and management practices of ecosystem dynamics. Sense-making, collaborative learning, and creating public awareness were part of the process. A comprehensive framework with a shared vision and goals that presented conservation as development and turned problems into possibilities was developed and contributed to a perception shift of the values of the wetland landscape among key actors. A window of opportunity at the political level opened in 1989, which made it possible to transform the governance system into a trajectory of ecosystem management. The transformation involved the establishment of a new municipality organization, EKW. This flexible organization serves as a bridge between local actors and governmental bodies and NGOs at different organizational levels. Such a bridging organization is critical in the adaptive governance of the wetland landscape. It is also critical in initiating and maintaining social-ecological processes and strategies that contribute to resilience such as developing motivation and values for ecosystem management, directing the local context through adaptive co-management, and navigating the larger sociopolitical and economic environment.

Major vulnerabilities. KW's vulnerabilities include dependence on a few key individuals and on the European Union's system of agricultural subsidies, the Common Agricultural Policy. Although EKW is a flexible organization with no legal authority, it has taken initiatives for land use plans that have been sanctioned by the municipality or national agencies. The present application to become part of the Man and the Biosphere Program is another means to decrease vulnerabilities.

Role of local stewards. Social-ecological inventories are useful for providing the baseline information on ecosystem condition and existing management, and for strengthening capacity to manage ecosystems. Local stewards can provide local ecological knowledge derived from detailed, long-term monitoring and active management of ecosystem services. In addition, they often collaborate within horizontal and vertical networks with shared management responsibilities (adaptive co-management). Thus local steward associations can play an important role in ecosystem management, and should be included in efforts to strengthen capacity to manage ecosystems for human well-being.

Added value of community-level assessments. Community-based assessments include fine-scale processes that are hidden at larger scales. They also involve local users and managers, who directly influence the ecosystem. In doing this, they can reveal local ecological knowledge which

is site-specific, detailed and long-term, and complements scientific knowledge. Communities can also give lessons for sustainability, in the sense that they have managed their ecosystems for a long time. In addition, strengthening capacity to manage ecosystems sustainably requires involvement of all people who shape the ecosystem.

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Budget, funding: Total budget is around $200,000 annually. Project donors are the Swedish Research Council for Environment, Agricultural Sciences, and Spatial Planning and the Swedish Research Council. In-kind contributions were provided by the Centre for Transdisciplinary Environmental Research and the Department of Systems Ecology, Stockholm University.

Acknowledgments: We would like to thank all the local stewards in Kristianstad who have contributed to the assessment, especially the Ecomuseum Kristianstads Vattenrike. Thanks also to the Resilience Alliance for important contributions during the meeting held in Kristianstad in September 2003. Finally, we thank our donors and the staff at the MA secretariat for enabling this assessment.

Stockholm Urban Assessment (Sweden SU)

(See color version of locator map in Appendix A.)

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Advisory committee: Peter Schantz, Stockholm University College of Physical Education and Sports, and Stefan Lundberg, Swedish Museum of Natural History.

Time period: 2001–2005.

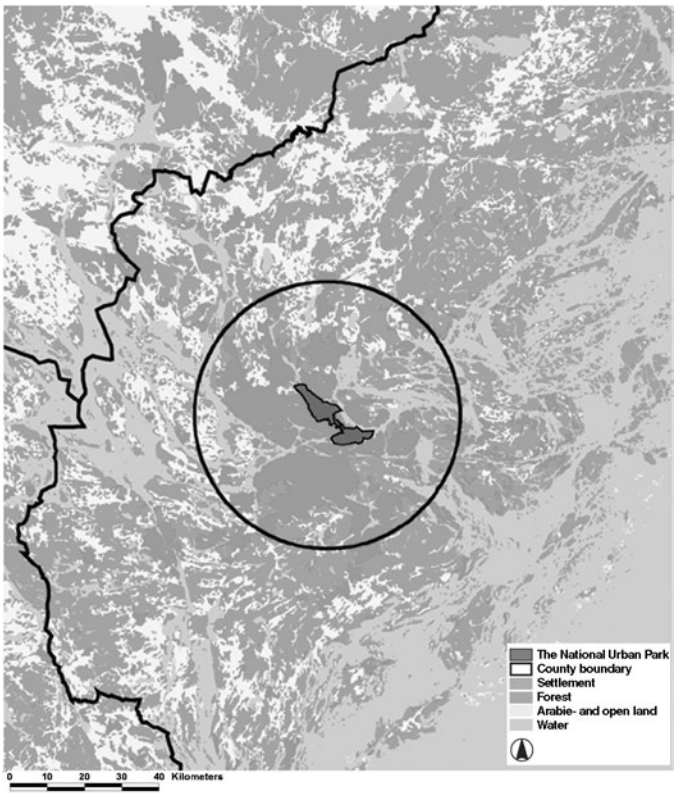
Area description:
Stockholm County consists of a total land and water area of 678,500 hectares, representing about 2% of the total land area of Sweden, and extending about 180 kilometers from north to south; 46% of the land area constitutes forest, 18% agricultural lands, 14% settled areas, and 22% represents other land uses (Statistical Yearbook of Sweden 1998).

Stockholm County has the largest population concentration in Sweden, with more than 1.8 million people, and is projected to grow to 2.4 million people within 30 years. Due to population increase and urban development, the region displays degradation of ecosystems, with a loss of both common and red listed species. The overall objectives of the Stockholm Urban assessment are to investigate how adaptive capacity can be built to better adapt to change and, more specifically, to find effective ways to manage urban ecosystem services. Stockholm Urban covers the greater metropolitan area of Stockholm and has at its center the Stockholm National Urban Park (NUP), a 2,700 hectare woodland area located adjacent to the inner city of Stockholm.

Methods and approaches:
The urban assessment focuses on the provision of ecosystem services and functions and the support provided by green areas. The role of local users, their management practices, institutional arrangements, and local ecological knowledge in the use and management of unprotected green areas is investigated. Recreation represents an important ecosystem service generated by urban green areas, and it is estimated that NUP has 15 million visitors per year and that 97% of the urban population in Stockholm will visit one of the urban green areas once a year; 47% will make visits every week.

The main direct drivers analyzed are green area loss, which leads to loss of aesthetic, recreational, and cultural values that in turn may lead to reduced human health and well-being. The *main indirect driver* leading to green area loss is population growth, with the associated urban sprawl, drivers that are reinforced by economic growth, coupled with institutional mismatches for ecosystem management and a lack of understanding of ecological support functions.

The common response to mitigate the effects of green area and biodiversity loss has been ratification of conventions and development



The Stockholm Urban Assessment. This assessment is located within a circle with a radius of 20 km surrounding the most central parts of the city. The National Urban Park is located in the center of this circle.

of new governmental policies, including establishment of nature reserves and national parks. Local public response also exists through interest groups that put pressure on authorities. Local stakeholders may also influence biodiversity management through their own land use and management practices. Linked to NUP alone, there are some 45 nongovernmental organizations representing 175,000 members that are loosely involved in green area management.

The methods and tools used include GIS assessments, gap analysis, and modeling; statistical trends; and inventories of key stakeholder groups with accompanying interviews. Key supplemental sources include a physical regional development plan by the County Council (RUFS 2001), and a new government program of reserves coordinated by the County Administrative Board.

Key findings:

Main conclusions from the analyses so far are that, in order to sustain ecosystem services, spatial and temporal interactions of ecosystem processes have to be recognized, and that these interactions have to be mimicked in appropriate spatial and temporal scales for management and communication. Our analyses also illustrate the great potential of management models of complex social-ecological systems, where scientific knowledge is combined with practices and knowledge that are generated among resource users locally in adaptive co-management processes. Co-management already exists in some parts of Stockholm County. For example, a wetland project known as ''Tyreså-projektet'' within a major system of lakes south of Stockholm aims to coordinate the lake management among six municipalities, and to handle upstream/downstream problems related to eutrophication. A major future aim will be to evaluate the prospects of introducing arenas of adaptive co-management to supplement the current management paradigm. Such arenas may be especially useful to establish around unprotected green areas managed by local stakeholders that promote ecological support functions. Co-management may also be useful in areas where protected areas exist and where locally managed green space may function as buffer zones and for management of weak links that connect larger green areas. A challenge in this context is to analyze management practices and local ecological knowledge among the locally evolved interest groups in order to strengthen their role in adaptive co-management processes and to engage them in monitoring and evaluation of outcomes from management projects.

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Funding: Donors for the project were the Swedish Research Council for Environment, Agricultural Sciences, and Spatial Planning and the Swedish Research Council. In-kind contributions were provided by the Centre for Transdisciplinary Environmental Research and the Department of Systems Ecology, Stockholm University.

Acknowledgments: We would like to thank all the local stewards in Stockholm who contributed to the assessment. We would also thank our donors and the staff at the MA secretariat for enabling this assessment.

Northern Range, Trinidad

(See color version of locator map in Appendix A.)

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Project co-sponsors: the Cropper Foundation, the University of the West Indies, the Tropical Re-Leaf Foundation, the Trust for Sustainable Livelihoods, the Environmental Management Authority.

Project team: The technical work of the assessment is being undertaken by individuals representing a fairly wide range of expertise and disciplines drawn from a consortium of local organizations. Leadership and oversight for the technical work is being provided by a Steering Committee of 13 members, who represent the project's organizing partners (nongovernmental organizations, public authority, university) plus others.

Advisory group: The Advisory Group comprises 13 members, representing the main user groups, and includes individuals from key public and corporate entities, as well as civil society and community organizations, all serving in their personal capacities.

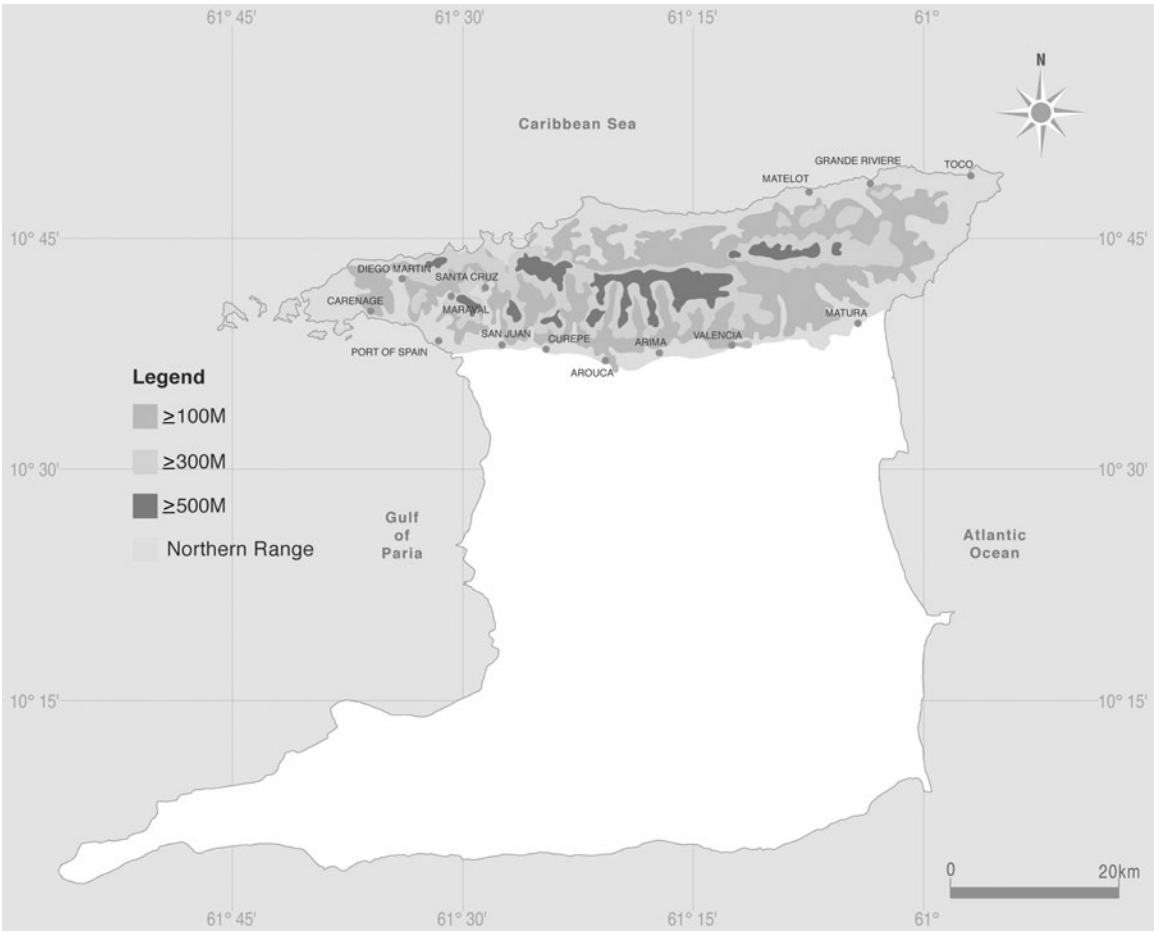
Time period: Planning for the Northern Range Assessment began in October 2002; the project was formally launched in March 2003, and is scheduled to be completed in mid-2005.

Year range for condition and trends analysis: Overall, the period for which the assessment of condition of, and trends in, Northern Range (NR) ecosystem services is undertaken varies among the services because of unevenness in the data. Much of the analysis therefore relies on expert opinions and qualitative information rather than on quantitative data.

Year range for scenarios projections: 2000–2025, extending beyond the national vision exercise for 2020.

Summary of important findings:
The Northern Range contributes to human well-being through the provision of fresh water, land space for housing and agriculture, and food; and through its considerable amenity value. There is evidence of extensive land conversion and forest degradation especially within the more accessible valleys of the southern slopes and especially in the western reaches of the range, close to the urban center. These, together with housing and agricultural settlements, authorized and unauthorized, on the slopes of many of the valleys, and unregulated quarrying sites have impacted negatively on freshwater resources. The northern slopes are steeper, less easily accessible, and less densely populated, and are consequently less disturbed than the southern slopes. There are many policy instruments and regulations relating specifically to the NR, but these are generally poorly implemented and enforced. Several public, community, and civic initiatives are being undertaken to contribute to restoration and improved management of Northern Range assets.

Forest resources. Approximately 75% of NR land is owned by the state. It is estimated that 67.5% of the range is currently forested, of which



Map of Trinidad, Highlighting Topography and Major Towns of the Northern Range (Kenny 2000)

85% to 95% is primary forest. Extensive conversion and a high incidence of human-caused forest fires are the main threats to forest resources, with the resulting effects being increased surface runoff and soil erosion, leading to a greater frequency of flood events and an overall decrease in surface water quality. About 14.8 % of the NR is designated as forest reserves to which restrictions apply. In addition, approximately 22% of NR land is under consideration as Environmentally Sensitive Areas that will contribute to forest conservation while providing for continued enjoyment of the amenity value. Several public, community, and civic initiatives to reforest and protect watersheds are in train.

Freshwater resources. The surface and groundwater resources of the NR are the primary source of fresh water for Trinidad, providing approximately 50% of Trinidad's potable water. The rivers are also important for recreational activities and for the harvesting of edible freshwater species. While the present overall quality is judged as good, and current supply exceeds demand, there is a trend of decreasing quality and quantity due to watershed degradation. It is projected that water availability per capita will decrease, and that by 2025 supply will barely meet demand, especially in the driest months. The cost of substituting the water provided by the NR with desalinated water is estimated at TTD804 million ($128 million) per year, based on performance of an existing desalinization plant in Trinidad. The government is attempting an integrated watershed management approach with its Draft National Water Resources Policy 2002 which establishes a framework for addressing issues such as land use planning, public water quality and supply, and flooding.

Coastal resources. The coasts of the NR contribute to human well-being through coastal fisheries, shoreline stabilization, and coastal water quality regulation, and are also the most popular beaches for recreational activities in the island. Sheltered harbors offer ideal conditions for marinas, which support a thriving and expanding boating industry. However, coastal development, land-based sources of pollution, inadequate services at recreational sites, and overexploitation of some popular species threaten these resources. There is competition for limited coastal land space, and this is exacerbated by the location of developments that are not shoreline dependent. The Draft National Water Resources Policy 2002 attempts to provide a framework for integrated coastal zone management.

Biodiversity. The biodiversity of the NR, considered at the species level, is important for its economic value in terms of timber and wild meat harvesting, and for its amenity value, especially as it relates to recreation and ecotourism development. However, species diversity, abundance, and distribution are all declining, especially in the western region of the range, due to land conversion and degradation, and overhunting of species. The ratification in 1996 of the Convention on Biological Diversity led to the development of the National Biodiversity Strategy and Action Plan in Trinidad and Tobago in 2001, with its main objectives being the improvement of the treatment of biodiversity issues in sectoral policies and plans and improved policy commitment and enforcement, as well as community involvement in helping to preserve the biodiversity resources of the Northern Range. Several community initiatives are currently in process to help protect vulnerable species while making small contributions to household income.

References: This assessment draws on a wide range of published and unpublished information, interviews with experts, consultations with three Northern Range communities, and on the MA conceptual framework.

Funding: The majority of the professional effort required for conducting the assessment is being provided on a voluntary basis by collaborators on the project (Steering Committee, including the project cosponsors, Working Group members, community members, Advisory Group). Financial support is being provided by the MA, the British High Commission in Trinidad and Tobago, the Cropper Foundation, and the local UNDP/GEF Small Grants Programme.

Vilcanota, Peru

(See color version of locator map in Appendix A.)

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Location: The Vilcanota sub-region is located in the Peruvian Andes, near Cuzco.

Lead institution: The assessment will be undertaken by the International Center of Traditional Knowledge, Ecology, and Policies (CICTEP), which is a project of the Asociación ANDES, a community-based Quechua-Aymara organization working on conservation and livelihoods promotion in the Andes region. To undertake the assessment, CICTEP will work closely with the Ausangate Community Association (a community organization of Ausangate sub-region associated to ANDES) made up of the indigenous communities of Tinqui, Tayancany, Cotaña, Mahuayani, Pausipanpa, and Anjasi.

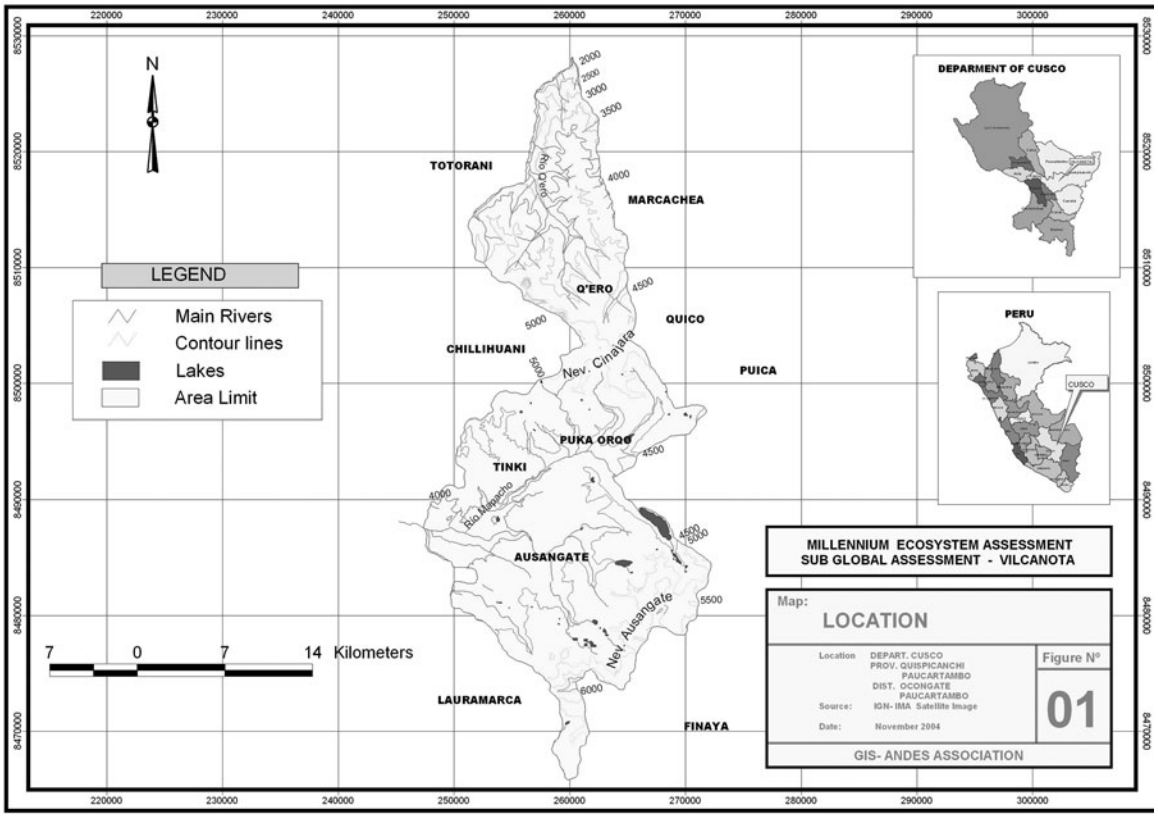
Focal issues: The main objective of this assessment is to assess the state of the ecosystem in the Vilcanota sub-region of the Peruvian Andes. It is imperative to do so as soon as possible due to the increasing intensity of global dynamics and drivers such as mass tourism and mining. These impacts are significant at the sub-regional and local level, particularly in terms of the ecological and socio-cultural dimensions. This may cause short and long term loss of capacity for self-reliance, and the erosion of biological and cultural diversity.

Ecosystem services being assessed: Spirituality, water, soil, agrobiodiversity.

Key features of the assessment:
The Vilcanota sub-region is the second most important ice-capped mountain range of the Peruvian Andes. It comprises 469 glaciers in an area of 539 square kilometers. The mountain range gives origin to an extended watershed system. The Ayacachi and Central Vilcanota systems are located in the northeast. In the north, the main systems are Qosnipata and Pilcopata, which border the Manu National Park. To the east the Marcapata and San Gaban are the main watersheds, and in the south is located the Vilcanota system which constitutes the Sacred Valley of the Incas. These systems border two main differentiated ecosystems at the regional level: the Amazon rainforest to the east and the Andean valleys to the west.

This ecosystem differentiation, as well as historical factors, have produced a very rich biological and cultural diversity in the region characterized by the existence of a large number of endemic species. Rich local knowledge and practices have made possible the adaptive management of natural resources for sustaining local livelihoods. Locals believe that systems and values, including the treatment of mountains as divinities, have allowed for the maintenance of a strong local cultural identity that approaches nature on the basis of concepts of relatedness to the natural world.

The area is also a known hot spot of biodiversity in the region, characterized by the existence of a large number of endemic species. It also an area of concentrated native agrobiodiversity and livestock populations. Natural resources are now under pressure and local land users have little means to improve their livelihoods. Present day changes and the influence of a liberalized world economy, particularly mining and tourism, have created social and cultural tensions and ecological degradation, making it particularly crucial to carry out an ecosystem assessment in this important ecoregion.



Vilcanota, Peru

The primary users of the assessment will be the communities of Tinqui, Tayancany, Cotaña, Mahuayani, Pausipanpa, Anjasi which form the Ausangate assessment area. Surrounding communities and the municipality of Ocangate will also use the assessment. The assessment will be completely user-driven.

Time frame, budget: The total cost is $127,000. The assessment will take place during the period 2003–2005. Partial funding was given by the MA.

Downstream Mekong River Wetlands, Viet Nam (Downstream Mekong)

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The project has been conducted by an assessment team that is headed by Dr. Mai Trong Thong (Institute of Geography) and includes approximately 30 scientists and experts employed at Institute of Geography, Institute of Ecology and Biological Resources, and Institute of Physics, Vietnamese Academy of Science and Technology (Hanoi), and University of Can Tho (Can Tho city).

The assessment team has been supported by an Advisory Committee encompassing experienced scientists from the Institute of Geography, experts from Institute of Development Strategy (Ministry of Planning and Investment) and local decision-makers.

Time period: The time range for the conditions and trends assessment is 1980–2002.

Summary of key findings:
The downstream Mekong wetlands (also known as the Cuu Long River Delta or Mekong Delta) covers an area of 39,000 square kilometers and is home to 16.1 million people (2001), with favorable conditions for agriculture and aquaculture. Since the 1980s, the intensified development of regional agricultural and aquaculture production has brought about a breakthrough in poverty alleviation. Local income of the poorest had increased by 50% by 2001, compared to 1995. The miracle in regional economic growth, unfortunately, parallels the sharp degradation of ecosystems and ecosystem services, which in turn challenges local human well-being. In looking at the conditions and trends of regional ecosystem services using the MA integrated assessment methodology, the assessment in its first phase identified drivers of the degradation in the condition of ecosystems, and identified out-of-control exploitation practices and policies, which resulted from economic pressure and overpopulation and are linked to rapid change in land use associated with market regulations. Up to 1999, the condition of ecosystem services was declining. Thanks to agricultural restructuring, amended planning options, and more serious management, the condition of regional ecosystems has tended to improve since 2000. Such findings concerning regional ecosystem services, some of which are stated below, captures not the entire, but the core, picture of the regional ecosystems.

Rice, fish, and shrimp as provisioning services. Provisioning of rice, fish, and shrimp are the most significant services of ecosystems in the Downstream Mekong wetlands. The extensive conversion of wetlands into paddy fields started in late 1980s and made the region the biggest rice producer nationwide. After this came the development of fish and shrimp production, which was a new milestone in the regional and national export-led economies. The economic blossoming in the areas led to a jump in regional poverty reduction on the one hand and, unfortunately, a degraded state of ecosystems on the other hand, including decreasing biodiversity and a polluted environment.

Timber and non-wood forest products. Known as a region having a large area of melaleuca and mangrove forests, timber and non-wood forest products remain basic benefits to some local communities. These products include timber, fuelwood, construction materials, food (mammals, amphibians, reptiles and birds, and vegetables), medicines, etc. As a result of large-scale destruction of forests, many of these products are becoming rare or extinct. Forest inhabitants are struggling to escape deep poverty through the direct exploitation of forests and are subject to increasing scarcity of forest goods and services.

Regulating services: alum soil and fresh water. The available literature shows very little analysis or assessment on regulating services of the downstream Mekong wetlands and what studies have been undertaken are almost all qualitative and not thorough, which caused considerable difficulty for the assessment team in approaching this analysis. In the region, there are two areas of regulating services of most interest. One is alum soil regulation and the other is freshwater regulation. Wetland ecosystems along with flooding systems are helpful factors preventing pyrite from being oxidized to form sulphate as well as dissolving and washing away generated acid. At the same time, the wetlands, in particular the melaleuca forests, are recognized as playing a vital role in regional water regulation. Recently, human activities including irrigation and drainage construction have weakened the natural alum-washing process and water storage and purification, which in turn has affected the sustainability of agricultural production.

Cultural services. This region with poetic landscapes is inspirational and, at the same time, is the birthplace of many performance arts such as Ca nhac tai tu, Ca vong co, etc. Riverine scenes, orchards, trade villages, bird sanctuaries, special use forests, which are typically available in the region, are potential sites for ecotourism. At the same time, folk tourism that focuses on tourist activities associated with historical vestiges, religious works (Khmer pagodas, Ba Chua Nui Sam temple, etc.), and traditional festivals (Ngo junk competition, etc.) has been the focus of local communities.

For further information: The full study of the conditions and trends will be published as Downstream Mekong River Wetland Ecosystems: Conditions and Trends Assessment. Key findings will be summarized in a summary for decision-makers.

Funding: The planning phase ($5,000) and the conditions and trends assessment phase ($55,000) were funded by the MA, with significant in-kind contributions from the Institute of Geography and local authorities. Fundraising for the scenarios and responses phase of the assessment is in process.

Western China

(See color version of locator map in Appendix A.)

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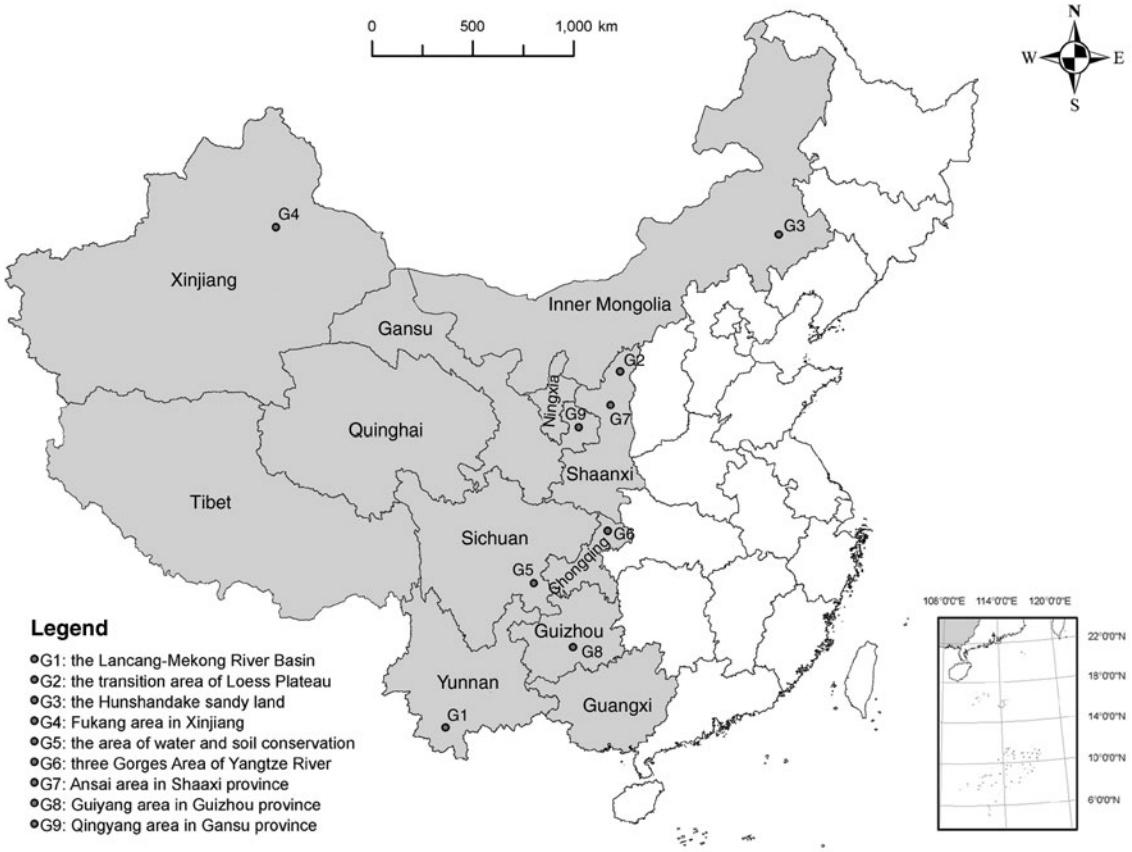
Assessment area: The decision to prioritize the development of the western region of China is a significant step taken by the government of China. The Western China ecosystem assessment aims to help protect and improve the ecosystem services of the western region of China and to enhance their contributions to the successful implementation of the western development strategy by considering a menu of possible policy and management options for sustaining ecosystem services. The western region of China, which has been economically backward and ecologically fragile, administratively consists of 12 provinces, including 5 provinces in southwest China, 5 provinces in northwest China, the Inner Mongolia Autonomous region, and the Guangxi Zhuang Autonomous region. The five provinces in southwest China are Sichuan province, Chongqing city, Yunnan province, Guizhou province, and Tibet Autonomous region. The five provinces in northwest China are Shaanxi province, Gansu province, Ningxia Hui Autonomous region, Xinjiang Uygur Autonomous region, and Qinghai province. The land area of the western region of China is about 6.8 million square kilometers, accounting for 70% of the land area of China.

Assessment process: The work of the Western China assessment was funded by the Chinese government, and organized into 22 research teams and sub-teams. An International Advisory Committee was formed, which first met in November 2002 in Beijing, where the the primary outline of the assessment report was reviewed. Integration meetings were held, including leaders from the 22 research teams and sub-research teams of the Western China assessment, academic authorities in China, policy-makers from relevant departments of the central government, and officials from local governments. Team members also attended MA working group meetings. The final report was completed in early 2005.

Methods:
Ecological zoning of China was a necessary component of the integrated ecosystem assessment approach taken. Combining the water-thermal features and the topographical ones, China was divided into 10 first-level ecological zones. The first-level ecological zones were further classified into 54 second-level ecological divisions. On the basis of the ecological zoning and established information systems, models for analyzing ecosystem services were developed. Trends and scenarios for water and food supply services of various ecosystems, carbon storage,



The Western Region of China. The red points represent typical areas at local scale.

and biodiversity were analyzed by combining the developed models with geographical information systems (GIS).

To analyze the relationship between ecosystem services and human well-being as well as effects of human activities on ecosystems, the Western China assessment developed a method of surface modeling of population spatial distribution (SMPD), by which trends and scenarios of spatial population distribution were analyzed. A model of critical thresholds was developed, based on human carrying capacity of ecosystems and population density.

To deal with the issues of multiscale information integration and error problems of GIS, a method of high precision surface modeling (HPSM) was constructed in terms of the fundamental theorem of surfaces. Results of numerical tests show that different spatial scales have little impact on HPSM precision, which means that HPSM can solve multiscale problems. However, HPSM needs to employ a grid generation method so that standardized grid generation regulation of surface modeling may be established. Grid computing is a useful technique for solving the problems of computing capacity overload, which are caused by complex numerical simulations.

The responses chapter discusses protection and conservation activities, ecological countermeasures in different regions, and the grain-for-green policy. Scenarios of converting land use versus planned policy targets were developed in terms of the grain-for-green policy.

Findings: Driving forces

Population. Since the 1930s, China's population has increased about three times. Although the birth control policy has restrained rapid population growth, annual births still number more than 9.5 million China because of the huge population base. The results from SMPD show that human population distribution in China has ranged from high in the east to low in the western and middle regions of China during the period from 1930 to 2000.

Climate change. Since 1950, China has experienced a trend of climate warming and general increases in precipitation. Since the 1980s, the mean annual temperature has increased by 0.25 degrees Celsius. The warming climate trend was found in most parts of China, but with significant regional differences. The mean annual temperature is increased by 0.5 degrees Celsius north of latitude of 35 degrees north. However, temperature has been on a decreasing trend in some parts of Guanzhong Plain, in the higher reach of the Yangtze River, and in the south of the Yangtze River basin. Precipitation has increased in northwest China since 1980. There is a decreasing trend of precipitation in most parts of southwest China and in the southern part of Tibet Plateau. In northwest China, precipitation has increased to different degrees in spring, summer, and autumn.

Land-use and land-cover change. The significant trend in land-use and land-cover change in the western region of China during the period from 1990 to 2000 was that the area of cropland increased through the conversion of grassland or woodland. Almost 1.8 million hectares of new cropland were cultivated, and most of which was dry farming land. At the same time, grassland and woodland decreased by 2.1 million hectares and 0.3 million hectares respectively. Urbanization was also significant in the western region of China. The built-up area increased by almost 10% in the last decade.

The grain-for-green policy. In recent years, China's grain output has grown steadily. Several consecutive bumper harvests have left the country with huge stockpiles of grain. This has created good conditions for implementing a massive farmland-to-forests campaign. To compensate for losses, farmers will receive subsidies, in the form of grain and money, for turning cultivated land back into forest and pasture. To minimize income losses that farmers might suffer from forest and pasture restoration, it is suggested that where natural conditions allow, fruit and other commercially valuable trees be planted. While the government will provide seedlings, farmers will be responsible for taking care of the restored forests and pastures and will retain all the profits from planting trees and grass on cultivated land.

Findings: Ecosystem services

Potential farmland productivity. The analysis of change of photosynthetic-thermal farmland productivity in each province of the western region of China during the 1990s shows that the potential farmland productivity has increased in the northern region of Inner Mongolia Autonomous Region, Xinjiang Uygur Autonomous Region, and Ningxia Autonomous Region. This increase was mainly from the increase of photosynthetic-thermal productivity in drylands and paddy fields. The gross increase of photosynthetic-thermal farmland productivity in the western region of China overall was mainly from drylands. Combined with the land use change in the western region of China in 1990s, it can be concluded that the change of photosynthetic-thermal farmland productivity was closely related to the change in area under cultivation.

Water. The land area of northwest China constitutes 44.5% of the total land area of China, while annual water resources of 234.4 billion cubic meters on average are only 8% of the total annual water resources for the whole of China; further more, available water in the northwest is less than 120 billion cubic meters. In general, the inland basin in the northwest has great capacity for regulation of supply through ice and snow in the mountain glaciers, and the quantity of water resources is thus relatively stable.. Rainfall in southwest China is abundant. The annual water resources amount to 1,275.2 billion cubic meters, while the available water resources amount to less than 347 billion cubic meters. The total amount of water resources and the water resources per capita in southwest China are richer than the northwest China.

Biodiversity. Ecosystems in the western region of China include 171 types of forests, 85 types of wetlands, 94 types of bushes, 47 types of grasslands, 72 types of meadows, and 49 types of deserts as well as 21 different types of tundra, alpine cushion vegetation, and talus vegetation. Although there exist rich ecosystem types in the western region of China, biodiversity faces many threats. Field studies in the 1980s showed that deforestaton has not only reduced panda habitat from 25 million hectares in the 1970s to 13.9 million hectares in the 1980s, but has also fragmented panda habitat into dozens of small, isolated patches. Some 1,000 pandas were divided into more than 20 small groups by highways, rivers, clear-cutting sites, farmlands, and villages. The smallest existing giant panda population consists of only 3 to 5 individuals. Overgrazing and agricultural conversion have reduced both the extent and quality of grassland ecosystems. Long-term overgrazing has degraded more than half of these grasslands; some 25% has been severely degraded. Over the past 20 years, grass yields have been reduced by one-third.

São Paulo Greenbelt, Brazil

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Project institutions: The assessment is coordinated by the São Paulo State Forest Institute, and the preliminary assessment phase team was drawn from the following institutions: University of São Paulo (Education College, Architecture and Urbanism College, Agriculture College, São Carlos Engineering College), São Paulo State University, University of Campinas, Geological Institute, Botanical Institute, Institute of Agriculture Economics, International Ecology Institute, Fishing Institute.

Assessment focus: The São Paulo Green Belt Sub-global Assessment aims to provide the region's decision-makers with information on the importance of ecosystem services provided by the Green Belt to São Paulo and Santos metropolises, how the drivers generated by urbanization threaten the continuity of these vital processes, the consequences of these phenomena for human well-being, and the response options for dealing these issues.

Time period: The preliminary assessment phase was July–December 2003. The full assessment period is 2005–2007.

The following services were preliminarily assessed: supporting services (ecosystem condition and trends and major ecological processes), freshwater, food security, forest resources, climate regulation, run-off regulation, carbon sequestration, sustainable tourism, social benefits. The full assessment shall include more services as more researchers are being incorporated into the process. The list below summarizes the main services and their relevance to human well-being and biodiversity:

	Ecosystem Service	Description/Importance of Ecosystem Service
Supporting Services	ecological processes and biodiversity	The Atlantic Forest is one of Earth's richest biomes in biodiversity; maintaining its biological abundance is an ethical duty of the population and also important for protection of the biological safety of human beings. Locally, the Green Belt (GB) woods are important ecological corridors, true links connecting different forestland regions of Brazil.
Provisioning Services	underground and surface water supply and conservation	Water resources within the GB supply water to over 20 million people. Their endangerment can lead to a collapse in public supply, whose shortage is already felt today during the dry season. There is also a strong correlation between forests and water quality, with serious economic implications.
	food security	Today, 15% of the world's food is produced in backyards and small land tracts (Ian Douglas, Univ. of Manchester, 2002, personal communication). The GB has this tradition and today is one of Brazil's top organic produce regions . Besides, the choice for agriculture in areas surrounding cities is regarded as an alternative to the expansion of big cities.
	forest resources	The forest-originated raw material produced in the Green Belt is representative for São Paulo State's forest-based economy, mainly as a function of reforestation.
Regulating Services	climatic regulation	The SPGB relates directly to climate regulation in the region, in counterpoint to the urban area that causes temperature to rise (heat islands). It has been suggested that this phenomenon has some linkages to the issue of thermal balance that influences rainfall patterns, leading to heavy floods in urban areas.
	soil protection and run-off regulation	The GB controls soil erosion, regulates runoff, and minimizes floods and public calamities.
	carbon sequestration and pollutant reduction	The GB has 311,407 hectares of undergrowth and 84,620 hectares of reforestation, all growing vegetation playing an important part in sequestering the carbon dioxide generated by metropolises.
Cultural Services	social use	Metropolises like São Paulo and Santos lack green areas. The GB is often the only alternative for the population to be in contact with the natural environment. This is crucial for the physical and psychological health of the population.

References: R. Victor et al., ''Application of the Biosphere Reserve Concept to Urban Areas: The Case of the São Paulo City Green Belt Biosphere Reserve,'' available at http://www.unesco.org/mab/urban/urbandocs.htm.

Funding: The preliminary assessment was funded by UNESCO, São Paulo Forest Institute, and the Environment Ministry ($7,000), with substantial in-kind contributions from the mentioned institutions. For 2005, there will be financial contribution from the Forest Institute and the Environment Ministry (around $30,000). Other funding sources are being sought.

Trade, Poverty, and the Environment

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Lead institution: WWF's Macroeconomics Programme Office (MPO)

Project description:
Launched in 2002, the trade assessment project will be working through 2005 with partners in Chile, China, India, Madagascar, Mexico, South Africa, and Viet Nam, to identify impacts of trade liberalization on rural poverty and the environment (particularly land and water) but also to work with business, civil society, governments, and international bodies to minimize the adverse impacts and to assure the maximum contribution of global trade to rural livelihood and sustainability goals.

The project is divided in two stages of eighteen months each. The principal focus of the first stage is on analysis, undertaken by research teams in each of the participant countries, complemented by research and policy activities at the WWF-World Bank coordination unit in Washington, D.C. The principal focus of the second stage is on communication and outreach to be carried out by the WWF Network and WWF-MPO.

The goals of the project are to develop knowledge, mechanisms, and platforms for business, civil society, governments, and international organizations to: (1) identify trade polices, rules, and related institutional and management interventions that can better achieve human development and sustainability goals; (2) better understand the trade-offs involved—for the environment and the rural poor—in decisions concerning trade policy and rules; and (3) align institutional, management, and policy options with the level of governance where they can be most effective. These goals are drawn directly from the MA framework for assessment.

Our intent is to: (1) establish an open dialog with business, civil society, government, and international agencies; (2) develop an analytic understanding of impacts, opportunities, and options from a combination of country-based case studies and the international literature and debate; and (3) promote institutional, management, and policy options emerging from the work—through advocacy, capacity-building, and partnerships—at all scales, from the local to the international, and within the organizations engaged and supporting the project itself

The focus on case studies is based on the hypothesis that to identify the impacts and opportunities associated with trade liberalization we need to go beyond national averages and look at real people in real places. The case study countries are **Chile:** conversion of the Valdivian Forest to plantation and industrial production; **China:** intensification of agricultural production in the Central Yangtze; **India:** conversion of forest land and mangroves for aquaculture in West Bengal; **Madagascar:** conversion of forest areas to sisal and maize production in the Spiny Forest; **Mexico:** expansion of cattle ranching and related agricultural products in the Chihuahuan desert areas; **South Africa:** conversion of commercial agriculture to export; **Viet Nam:** expansion of coffee, rice and shrimp production in Truong Son Mountains.

The first project component to become associated with the MA is in India. It will be undertaken by the Institute of Economic Growth at Delhi University. The related outreach program will be the responsibility of WWF India. The Principal Investigator and Project Leader is Dr. Kanchan Chopra (kc@ieg.ernet.in); the Co-Project Investigator is Dr. Pushpam Kumar (pl@ieg.ernet.id); and Ms. Veera Kaul Singh is responsible for outreach (vsingh@wwfindia.net).

The case study will address the Sunderbans region of West Bengal, India. It is located at the apex of the Bay of Bengal, and is characterized by sandy beaches, mud flats, coastal dunes estuaries, creeks, inlets, and mangrove swamps. It is also home to national parks, tiger reserves, and other wildlife sanctuaries. The region is under ecological threat from a growing aquaculture industry.

The case study will address the following principle issues: the conditions in the coastal and marine ecosystem prior to acceleration of aquaculture for export; the associated level of well-being of different groups as a consequence of ecosystem services provided by the system; the plausible future changes in health, livelihood, and security made available to different groups in the region; the implication of these changes for disruption in the capability of the ecosystem to provide the level of services provided in the base-year; and recommendations to enhance the well-being and conserve the ecosystem (examining the trade-offs and synergies set in motion by different responses, strategies, and policy interventions).

The Northern Highlands Lake District, Wisconsin

(See color version of locator map in Appendix A.)

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Location: The Northern Highlands Lake District (NHLD) covers 5,300 square kilometers of the extreme northern part of Wisconsin, USA. It is to the south and east of Lake Superior at a latitude of 46°N.

Lead institution: University of Wisconsin, Madison. The assessment also involves people from the local business community, the Lac du Flambeau Band of Lake Superior Chippewa Indians, other residents of the region, recreational users, local government, NGOs, media representatives, and the State management agency (the Wisconsin Department of Natural Resources, or WDNR).

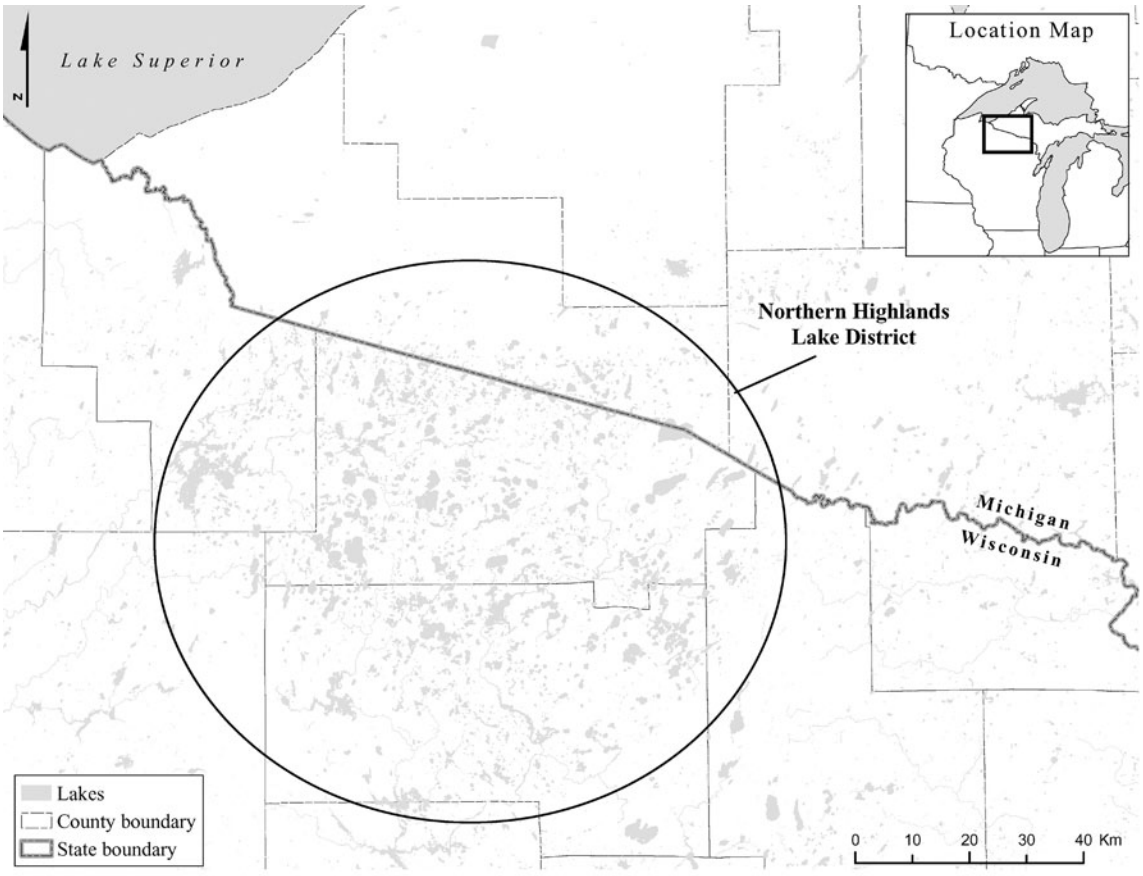
Focal issues:
The Northern Highlands Lake District of Wisconsin is in transition from a sparsely settled region to a more densely populated one. Expected changes offer benefits to northern Wisconsin residents, but also threaten to degrade the ecosystem services that residents ultimately rely on. Because the future of this region is uncertain, it is difficult to make decisions that will avoid potential risks and take advantage of potential opportunities.

Key issues derive from the rapid transition of the region driven by development. Conflict centers on multiple demands for limited land and water, especially limited lakeshore land. Social-ecological challenges include:

- growth and diversification of the economy,
- maintenance of traditional values (amid multiple definitions of "traditional"),
- competing use of resources (such as land for timber harvest versus recreational use),
- incompatible recreational uses (such as motorized versus silent outdoor recreation),
- population growth,
- impacts of forest management,
- overpopulation of deer,
- negative impacts of lakeshore development on water quality and fisheries,
- exotic species, and
- impacts of fish harvesting and stocking.

Many of these issues are addressed through workshops, scenarios, and scientific research.

Ecosystem services: We are addressing the ecosystem services provided by lakes in the NHLD. To assess the sustainability of these ecosystem services, we need to understand how different people use and transform ecosystems, the dynamics of ecosystems, and the external forces that are shaping the region. We therefore examine interactions among population and economic growth, lakeshore development, social conflict, regional-local institutions, forestry, hunting, fishing, biodiversity, ecotourism, ethnotourism, and other forms of recreation in the region.



Project outputs: In addition to producing assessment reports and scientific articles, we intend to become a ''virtual center'' for integrated, science-based understanding of the NHLD. We will maintain an ongoing discussion with local people and develop tools, such as scenarios, in collaboration with them. We aim to express our findings in plain language, simple computer games, art, and other formats that are widely understandable. We will establish a network of citizens in the region who are knowledgeable about navigating long-term change.

Key features of assessment region:
Lakes are a key characteristic of the NHLD, with thousands of natural lakes that together cover about 11% of the surface area in the region. An additional 25% of the area is wetland. Most lakes in this area are clear, with low amounts of nutrients. Most of the lakes receive their water from precipitation, although many are seepage lakes that are connected only by groundwater. Determinants of water quality include water color, nutrient input, presence of toxins (such as mercury), and presence of disease-causing organisms (such as *Giardia*). At the present time, water quality is good in most of the lakes. Many of the lakes support high-quality game fisheries. Walleye (*Stizostedion vitreum*) is the most popular sport and table fish. Important sport fisheries exist for muskellunge (*Esox masquinongy*), northern pike (*Esox lucius*), black basses (*Micropterus* spp.), and diverse panfish. Quality of sport fishing is sensitive to harvest, as is evident from the high catch rates and abundant trophy-size fishes in lakes that are managed with regulations that restrict harvest. In addition to fish harvest, other important effects of people on the lakes include removal of woody habitat from nearshore areas, introduction of destructive exotic species (especially rusty crayfish, *Orconectes rusticus,* rainbow smelt (*Osmerus mordax*), and Eurasian milfoil *Myriophyllum spicatum*), nutrient enrichment, deposition of mercury (from coal-fired industries far to the west of the NHLD), and hydrological modifications.

Ecosystem services derived from the NHLD are dominated by tourism and forest products. Tourism is based on the natural beauty of the area, the abundant wildlife (including diverse non-game species plus popular game species such as ducks, grouse and deer), and the legendary fishing opportunities. Ethnotourism, centered on the Lac du Flambeau reservation, is a small but growing sector of the economy. Important outdoor activities include boating (from paddlecraft to large motorized boats), all-terrain vehicle use, and snowmobiling. Forestry centers on pulpwood for Wisconsin's thriving paper industry.

In addition to these readily quantified ecosystem services, the NHLD contributes a number of ecosystem services that are not often quantified. Two important tributaries of the Mississippi River, the Wisconsin and St. Croix rivers, arise in the NHLD. Waters from the NHLD also flow to Lake Superior. Thus the NHLD is an important source of clean water for two of the major river systems of North America, the Mississippi and the St. Lawrence. The aggrading forests of the NHLD may be significant carbon sinks (although the carbon budget of the landscape has not yet been quantified). The thousands of individual lakes harbor remarkable genetic diversity of aquatic organisms. This diversity has been quantified only partially. Unfortunately, fish stocking practices and invasions of exotic species are eroding this diversity of aquatic resources.

For further information:
http://limnology.wisc.edu/NHLD/index.htm. A Web page with basic information about the project and additional links.
http://www.ecologyandsociety.org/vol7/iss3/art1. A peer-reviewed published paper about the NHLD and the scenarios developed on the possible futures of the region.
http://www.lakefutures.wisc.edu. A description of the scenarios.

Timeframe, budget: Open-ended timeframe. Funding is mainly from University of Wisconsin.

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Appendix D

Abbreviations and Acronyms

AI	aridity index
AKRSP	Aga Khan Rural Support Programme
AMF	arbuscular mycorrhizal fungi
ASB	alternatives to slash-and-burn
ASOMPH	Asian Symposium on Medicinal Plants, Spices and Other Natural Products
AVHRR	advanced very high resolution radiometer
BCA	benefit-cost analysis
BGP	Biogeochemical Province
BII	Biodiversity Intactness Index
BMI	body mass index
BNF	biological nitrogen fixation
BOOT	build-own-operate-transfer
BRT	Bus Rapid Transit (Brazil)
BSE	bovine spongiform encephalopathy
Bt	*Bacillus thuringiensis*
C&I	criteria and indicators
CAFO	concentrated animal feeding operations
CAP	Common Agricultural Policy (of the European Union)
CAREC	Central Asia Regional Environment Centre
CBA	cost-benefit analysis
CBD	Convention on Biological Diversity
CBO	community-based organization
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CCN	cloud condensation nuclei
CCS	CO_2 capture and storage
CDM	Clean Development Mechanism
CEA	cost-effectiveness analysis
CENICAFE	Centro Nacional de Investigaciones de Café (Colombia)
CFCs	chlorofluorocarbons
CGIAR	Consultative Group on International Agricultural Research
CIFOR	Center for International Forestry Research
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)
CONICET	Consejo de Investigaciones Científicas y Técnicas (Argentina)
COP	Conference of the Parties (of treaties)
CPF	Collaborative Partnership on Forests
CSIR	Council for Scientific and Industrial Research (South Africa)
CV	contingent valuation
CVM	contingent valuation method
DAF	decision analytical framework
DALY	disability-adjusted life year
DDT	dichloro diphenyl trichloroethane
DES	dietary energy supply
DHF	dengue hemorrhagic fever
DHS	demographic and health surveys
DMS	dimethyl sulfide
DPSEEA	driving forces-pressure-state-exposure-effect-action
DPSIR	driver-pressure-state-impact-response
DSF	dust storm frequency
DU	Dobson Units
EEA	European Environment Agency
EEZ	exclusive economic zone
EGS	ecosystem global scenario
EHI	environmental health indicator
EIA	environmental impact assessment
EID	emerging infectious disease
EKC	Environmental Kuznets Curve
EMF	ectomycorrhizal fungi

E/MSY	extinctions per million species per year
ENSO	El Niño/Southern Oscillation
EPA	Environmental Protection Agency (United States)
EPI	environmental policy integration
EU	European Union
EU ETS	European Union Emissions Trading System
FAO	Food and Agriculture Organization (United Nations)
FAPRI	Food and Agriculture Policy Research Institute
FLEGT	Forest Law Enforcement, Governance, and Trade
FRA	Forest Resources Assessment
FSC	Forest Stewardship Council
GATS	General Agreement on Trade and Services
GATT	General Agreement on Tariffs and Trade
GCM	general circulation model
GDI	Gender-related Development Index
GDP	gross domestic product
GEF	Global Environment Facility
GEO	*Global Environment Outlook*
GHG	greenhouse gases
GIS	geographic information system
GIWA	Global International Waters Assessment
GLASOD	Global Assessment of Soil Degradation
GLC	Global Land Cover
GLOF	Glacier Lake Outburst Flood
GM	genetic modification
GMO	genetically modified organism
GNI	gross national income
GNP	gross national product
GPS	Global Positioning System
GRoWI	*Global Review of Wetland Resources and Priorities for Wetland Inventory*
GSG	Global Scenarios Group
GSPC	Global Strategy for Plant Conservation
GtC-eq	gigatons of carbon equivalent
GWP	global warming potential
HDI	Human Development Index
HIA	health impact assessment
HIPC	heavily indebted poor countries
HPI	Human Poverty Index
HPS	hantavirus pulmonary syndrome
HWB	human well-being
IAA	integrated agriculture-aquaculture
IAM	integrated assessment model
IBI	Index of Biotic Integrity
ICBG	International Cooperative Biodiversity Groups
ICDP	integrated conservation and development project
ICJ	International Court of Justice
ICRAF	International Center for Research in Agroforestry
ICRW	International Convention for the Regulation of Whaling
ICSU	International Council for Science
ICZM	integrated coastal zone management
IDRC	International Development Research Centre (Canada)
IEA	International Energy Agency
IEG	international environmental governance
IEK	indigenous ecological knowledge
IFPRI	International Food Policy Research Institute
IGBP	International Geosphere-Biosphere Program
IIASA	International Institute for Applied Systems Analysis
IK	indigenous knowledge
ILO	International Labour Organization
IMF	International Monetary Fund
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
IMR	infant mortality rate
INESI	International Network of Sustainability Initiatives (hypothetical, in *Scenarios*)
INTA	Instituto Nacional de Tecnología Agropecuaria (Argentina)
IPAT	impact of population, affluence, technology
IPCC	Intergovernmental Panel on Climate Change
IPM	integrated pest management
IPR	intellectual property rights
IRBM	integrated river basin management
ISEH	International Society for Ecosystem Health
ISO	International Organization for Standardization
ITPGR	International Treaty on Plant Genetic Resources for Food and Agriculture
ITQs	individual transferable quotas
ITTO	International Tropical Timber Organization
IUCN	World Conservation Union
IUU	illegal, unregulated, and unreported (fishing)
IVM	integrated vector management

IWMI	International Water Management Institute
IWRM	integrated water resources management
JDSD	Johannesburg Declaration on Sustainable Development
JI	joint implementation
JMP	Joint Monitoring Program
LAC	Latin America and the Caribbean
LAI	leaf area index
LARD	livelihood approaches to rural development
LDC	least developed country
LEK	local ecological knowledge
LME	large marine ecosystems
LPI	Living Planet Index
LSMS	Living Standards Measurement Study
LULUCF	land use, land use change, and forestry
MA	Millennium Ecosystem Assessment
MAI	mean annual increments
MBI	market-based instruments
MCA	multicriteria analysis
MDG	Millennium Development Goal
MEA	multilateral environmental agreement
MENA	Middle East and North Africa
MER	market exchange rate
MHC	major histocompatibility complex
MICS	multiple indicator cluster surveys
MIT	Massachusetts Institute of Technology
MPA	marine protected area
MSVPA	multispecies virtual population analysis
NAP	National Action Program (of desertification convention)
NBP	net biome productivity
NCD	noncommunicable disease
NCS	National Conservation Strategy
NCSD	national council for sustainable development
NDVI	normalized difference vegetation index
NE	effective size of a population
NEAP	national environmental action plan
NEP	new ecological paradigm; also net ecosystem productivity
NEPAD	New Partnership for Africa's Development
NFAP	National Forestry Action Plan
NFP	national forest programs
NGO	nongovernmental organization
NIH	National Institutes of Health (United States)
NMHC	non-methane hydrocarbons
NOAA	National Oceanographic and Atmospheric Administration (United States)
NPP	net primary productivity
NSSD	national strategies for sustainable development
NUE	nitrogen use efficiency
NWFP	non-wood forest product
ODA	official development assistance
OECD	Organisation for Economic Co-operation and Development
OSB	oriented strand board
OWL	other wooded land
PA	protected area
PAH	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PEM	protein energy malnutrition
PES	payment for environmental (or ecosystem) services
PFT	plant functional type
PNG	Papua New Guinea
POPs	persistent organic pollutants
PPA	participatory poverty assessment
ppb	parts per billion
PPI	potential Pareto improvement
ppm	parts per million
ppmv	parts per million by volume
PPP	purchasing power parity; also public-private partnership
ppt	parts per thousand
PQLI	Physical Quality of Life Index
PRA	participatory rural appraisal
PRSP	Poverty Reduction Strategy Paper
PSE	producer support estimate
PVA	population viability analysis
RANWA	Research and Action in Natural Wealth Administration
RBO	river basin organization
RIDES	Recursos e Investigación para el Desarrollo Sustentable (Chile)
RIL	reduced impact logging
RLI	Red List Index
RO	reverse osmosis

RRA rapid rural appraisal

RUE rain use efficiency

SADC Southern African Development Community

SADCC Southern African Development Coordination Conference

SAfMA Southern African Millennium Ecosystem Assessment

SAP structural adjustment program

SAR species-area relationship

SARS severe acute respiratory syndrome

SBSTTA Subsidiary Body on Scientific, Technical and Technological Advice (of CBD)

SEA strategic environmental assessment

SEME simple empirical models for eutrophication

SES social-ecological system

SFM sustainable forest management

SIDS small island developing states

SMS safe minimum standard

SOM soil organic matter

SRES Special Report on Emissions Scenarios (of the IPCC)

SSC Species Survival Commission (of IUCN)

SWAP sector-wide approach

TAC total allowable catch

TBT tributyltin

TC travel cost

TCM travel cost method

TDR tradable development rights

TDS total dissolved solids

TEIA transboundary environmental impact assessment

TEK traditional ecological knowledge

TEM terrestrial ecosystem model

TESEO Treaty Enforcement Services Using Earth Observation

TEV total economic value

TFAP Tropical Forests Action Plan

TFP total factor productivity

TFR total fertility rate

Tg teragram (10^{12} grams)

TK traditional knowledge

TMDL total maximum daily load

TOF trees outside of forests

TRIPS Trade-Related Aspects of Intellectual Property Rights

TSU Technical Support Unit

TW terawatt

UMD University of Maryland

UNCCD United Nations Convention to Combat Desertification

UNCED United Nations Conference on Environment and Development

UNCLOS United Nations Convention on the Law of the Sea

UNDP United Nations Development Programme

UNECE United Nations Economic Commission for Europe

UNEP United Nations Environment Programme

UNESCO United Nations Educational, Scientific and Cultural Organization

UNFCCC United Nations Framework Convention on Climate Change

UNIDO United Nations Industrial Development Organization

UNRO United Nations Regional Organization (hypothetical body, in *Scenarios*)

UNSO UNDP's Office to Combat Desertification and Drought

USAID U.S. Agency for International Development

USDA U.S. Department of Agriculture

VOC volatile organic compound

VW virtual water

WBCSD World Business Council for Sustainable Development

WCD World Commission on Dams

WCED World Commission on Environment and Development

WCMC World Conservation Monitoring Centre (of UNEP)

WFP World Food Programme

WHO World Health Organization

WIPO World Intellectual Property Organization

WISP weighted index of social progress

WMO World Meteorological Organization

WPI Water Poverty Index

WRF white rot fungi

WSSD World Summit on Sustainable Development

wta withdrawals-to-availability ratio (of water)

WTA willingness to accept compensation

WTO World Trade Organization

WTP willingness to pay

WWAP World Water Assessment Programme

WWF World Wide Fund for Nature

WWV World Water Vision

Appendix E

Glossary

Abatement cost: See *Marginal abatement cost*.

Abundance: The total number of individuals of a taxon or taxa in an area, population, or community. Relative abundance refers to the total number of individuals of one taxon compared with the total number of individuals of all other taxa in an area, volume, or community.

Active adaptive management: See *Adaptive management*.

Adaptation: Adjustment in natural or human systems to a new or changing environment. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.

Adaptive capacity: The general ability of institutions, systems, and individuals to adjust to potential damage, to take advantage of opportunities, or to cope with the consequences.

Adaptive management: A systematic process for continually improving management policies and practices by learning from the outcomes of previously employed policies and practices. In active adaptive management, management is treated as a deliberate experiment for purposes of learning.

Afforestation: Planting of forests on land that has historically not contained forests. (Compare *Reforestation*.)

Agrobiodiversity: The diversity of plants, insects, and soil biota found in cultivated systems.

Agroforestry systems: Mixed systems of crops and trees providing wood, non-wood forest products, food, fuel, fodder, and shelter.

Albedo: A measure of the degree to which a surface or object reflects solar radiation.

Alien species: Species introduced outside its normal distribution.

Alien invasive species: See *Invasive alien species*.

Aquaculture: Breeding and rearing of fish, shellfish, or plants in ponds, enclosures, or other forms of confinement in fresh or marine waters for the direct harvest of the product.

Benefits transfer approach: Economic valuation approach in which estimates obtained (by whatever method) in one context are used to estimate values in a different context.

Binding constraints: Political, social, economic, institutional, or ecological factors that rule out a particular response.

Biodiversity (a contraction of biological diversity): The variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part. Biodiversity includes diversity within species, between species, and between ecosystems.

Biodiversity regulation: The regulation of ecosystem processes and services by the different components of biodiversity.

Biogeographic realm: A large spatial region, within which ecosystems share a broadly similar biota. Eight terrestrial biogeographic realms are typically recognized, corresponding roughly to continents (e.g., Afrotropical realm).

Biological diversity: See *Biodiversity*.

Biomass: The mass of tissues in living organisms in a population, ecosystem, or spatial unit.

Biome: The largest unit of ecological classification that is convenient to recognize below the entire globe. Terrestrial biomes are typically based on dominant vegetation structure (e.g., forest, grassland). Ecosystems within a biome function in a broadly similar way, although they may have very different species composition. For example, all forests share certain properties regarding nutrient cycling, disturbance, and biomass that are different from the properties of grasslands. Marine biomes are typically based on biogeochemical properties. The WWF biome classification is used in the MA.

Bioprospecting: The exploration of biodiversity for genetic and biochemical resources of social or commercial value.

Biotechnology: Any technological application that uses biological systems, living organisms, or derivatives thereof to make or modify products or processes for specific use.

Biotic homogenization: Process by which the differences between biotic communities in different areas are on average reduced.

Blueprint approaches: Approaches that are designed to be applicable in a wider set of circumstances and that are not context-specific or sensitive to local conditions.

Boundary organizations: Public or private organizations that synthesize and translate scientific research and explore its policy implications to help bridge the gap between science and decision-making.

Bridging organizations: Organizations that facilitate, and offer an arena for, stakeholder collaboration, trust-building, and conflict resolution.

Capability: The combinations of doings and beings from which people can choose to lead the kind of life they value. Basic capability is the capability to meet a basic need.

Capacity building: A process of strengthening or developing human resources, institutions, organizations, or networks. Also referred to as capacity development or capacity enhancement.

Capital value (of an ecosystem): The present value of the stream of ecosystem services that an ecosystem will generate under a particular management or institutional regime.

Capture fisheries: See *Fishery*.

Carbon sequestration: The process of increasing the carbon content of a reservoir other than the atmosphere.

Cascading interaction: See *Trophic cascade*.

Catch: The number or weight of all fish caught by fishing operations, whether the fish are landed or not.

Coastal system: Systems containing terrestrial areas dominated by ocean influences of tides and marine aerosols, plus nearshore marine areas. The inland extent of coastal ecosystems is the line where land-based influences dominate, up to a maximum of 100 kilometers from the coastline or 100-meter elevation (whichever is closer to the sea), and the outward extent is the 50-meter-depth contour. See also *System*.

Collaborative (or joint) forest management: Community-based management of forests, where resource tenure by local communities is secured.

Common pool resource: A valued natural or human-made resource or facility in which one person's use subtracts from another's use and where it is often necessary but difficult to exclude potential users from the resource. (Compare *Common property resource*.)

Common property management system: The institutions (i.e., sets of rules) that define and regulate the use rights for common pool resources. Not the same as an open access system.

Common property resource: A good or service shared by a well-defined community. (Compare *Common pool resource*.)

Community (ecological): An assemblage of species occurring in the same space or time, often linked by biotic interactions such as competition or predation.

Community (human, local): A collection of human beings who have something in common. A local community is a fairly small group of people who share a common place of residence and a set of institutions based on this fact, but the word 'community' is also used to refer to larger collections of people who have something else in common (e.g., national community, donor community).

Condition of an ecosystem: The capacity of an ecosystem to yield services, relative to its potential capacity.

Condition of an ecosystem service: The capacity of an ecosystem service to yield benefits to people, relative to its potential capacity.

Constituents of well-being: The experiential aspects of well-being, such as health, happiness, and freedom to be and do, and, more broadly, basic liberties.

Consumptive use: The reduction in the quantity or quality of a good available for other users due to consumption.

Contingent valuation: Economic valuation technique based on a survey of how much respondents would be willing to pay for specified benefits.

Core dataset: Data sets designated to have wide potential application throughout the Millennium Ecosystem Assessment process. They include land use, land cover, climate, and population data sets.

Cost-benefit analysis: A technique designed to determine the feasibility of a project or plan by quantifying its costs and benefits.

Cost-effectiveness analysis: Analysis to identify the least cost option that meets a particular goal.

Critically endangered species: Species that face an extremely high risk of extinction in the wild. See also *Threatened species*.

Cross-scale feedback: A process in which effects of some action are transmitted from a smaller spatial extent to a larger one, or vice versa. For example, a global policy may constrain the flexibility of a local region to use certain response options to environmental change, or a local agricultural pest outbreak may affect regional food supply.

Cultivar (a contraction of cultivated variety): A variety of a plant developed from a natural species and maintained under cultivation.

Cultivated system: Areas of landscape or seascape actively managed for the production of food, feed, fiber, or biofuels.

Cultural landscape: See *Landscape*.

Cultural services: The nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g., knowledge systems, social relations, and aesthetic values.

Decision analytical framework: A coherent set of concepts and procedures aimed at synthesizing available information to help policymakers assess consequences of various decision options. DAFs organize the relevant information in a suitable framework, apply decision criteria (both based on some paradigms or theories), and thus identify options that are better than others under the assumptions characterizing the analytical framework and the application at hand.

Decision-maker: A person whose decisions, and the actions that follow from them, can influence a condition, process, or issue under consideration.

Decomposition: The ecological process carried out primarily by microbes that leads to a transformation of dead organic matter into inorganic mater.

Deforestation: Conversion of forest to non-forest.

Degradation of an ecosystem service: For *provisioning services,* decreased production of the service through changes in area over which the services is provided, or decreased production per unit area. For *regulating* and *supporting services,* a reduction in the benefits obtained from the service, either through a change in the service or through human pressures on the service exceeding its limits. For *cultural services,* a change in the ecosystem features that decreases the cultural benefits provided by the ecosystem.

Degradation of ecosystems: A persistent reduction in the capacity to provide ecosystem services.

Desertification: land degradation in drylands resulting from various factors, including climatic variations and human activities.

Determinants of well-being: Inputs into the production of well-being, such as food, clothing, potable water, and access to knowledge and information.

Direct use value (of ecosystems): The benefits derived from the services provided by an ecosystem that are used directly by an economic agent. These include consumptive uses (e.g., harvesting goods) and nonconsumptive uses (e.g., enjoyment of scenic beauty). Agents are often physically present in an ecosystem to receive direct use value. (Compare *Indirect use value*.)

Disability-adjusted life years: The sum of years of life lost due to premature death and illness, taking into account the age of death compared with natural life expectancy and the number of years of life lived with a disability. The measure of number of years lived with the disability considers the duration of the disease, weighted by a measure of the severity of the disease.

Diversity: The variety and relative abundance of different entities in a sample.

Driver: Any natural or human-induced factor that directly or indirectly causes a change in an ecosystem.

Driver, direct: A driver that unequivocally influences ecosystem processes and can therefore be identified and measured to differing degrees of accuracy. (Compare *Driver, indirect*.)

Driver, endogenous: A driver whose magnitude can be influenced by the decision-maker. Whether a driver is exogenous or endogenous depends on the organizational scale. Some drivers (e.g., prices) are exogenous to a decision-maker at one level (a farmer) but endogenous at other levels (the nation-state). (Compare *Driver, exogenous*.)

Driver, exogenous: A driver that cannot be altered by the decision-maker. (Compare *Driver, endogenous*.)

Driver, indirect: A driver that operates by altering the level or rate of change of one or more direct drivers. (Compare *Driver, direct*.)

Drylands: See *Dryland system*.

Dryland system: Areas characterized by lack of water, which constrains the two major interlinked services of the system: primary production and nutrient cycling. Four dryland subtypes are widely recognized: dry sub-humid, semiarid, arid, and hyperarid, showing an increasing level of aridity or moisture deficit. See also *System*.

Ecological character: See *Ecosystem properties*.

Ecological degradation: See *Degradation of ecosystems*.

Ecological footprint: An index of the area of productive land and aquatic ecosystems required to produce the resources used and to assimilate the wastes produced by a defined population at a specified material standard of living, wherever on Earth that land may be located.

Ecological security: A condition of ecological safety that ensures access to a sustainable flow of provisioning, regulating, and cultural services needed by local communities to meet their basic capabilities.

Ecological surprises: unexpected—and often disproportionately large—consequence of changes in the abiotic (e.g., climate, disturbance) or biotic (e.g., invasions, pathogens) environment.

Ecosystem: A dynamic complex of plant, animal, and microorganism communities and their non-living environment interacting as a functional unit.

Ecosystem approach: A strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use. An ecosystem approach is based on the application of appropriate scientific methods focused on levels of biological organization, which encompass the essential structure, processes, functions, and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems.

Ecosystem assessment: A social process through which the findings of science concerning the causes of ecosystem change, their consequences for human well-being, and management and policy options are brought to bear on the needs of decision-makers.

Ecosystem boundary: The spatial delimitation of an ecosystem, typically based on discontinuities in the distribution of organisms, the biophysical environment (soil types, drainage basins, depth in a

water body), and spatial interactions (home ranges, migration patterns, fluxes of matter).

Ecosystem change: Any variation in the state, outputs, or structure of an ecosystem.

Ecosystem function: See *Ecosystem process*.

Ecosystem interactions: Exchanges of materials, energy, and information within and among ecosystems.

Ecosystem management: An approach to maintaining or restoring the composition, structure, function, and delivery of services of natural and modified ecosystems for the goal of achieving sustainability. It is based on an adaptive, collaboratively developed vision of desired future conditions that integrates ecological, socioeconomic, and institutional perspectives, applied within a geographic framework, and defined primarily by natural ecological boundaries.

Ecosystem process: An intrinsic ecosystem characteristic whereby an ecosystem maintains its integrity. Ecosystem processes include decomposition, production, nutrient cycling, and fluxes of nutrients and energy.

Ecosystem properties: The size, biodiversity, stability, degree of organization, internal exchanges of materials, energy, and information among different pools, and other properties that characterize an ecosystem. Includes ecosystem functions and processes.

Ecosystem resilience: See *Resilience*.

Ecosystem resistance: See *Resistance*.

Ecosystem robustness: See *Ecosystem stability*.

Ecosystem services: The benefits people obtain from ecosystems. These include *provisioning services* such as food and water; *regulating services* such as flood and disease control; *cultural services* such as spiritual, recreational, and cultural benefits; and *supporting services* such as nutrient cycling that maintain the conditions for life on Earth. The concept ''ecosystem goods and services'' is synonymous with ecosystem services.

Ecosystem stability (or ecosystem robustness): A description of the dynamic properties of an ecosystem. An ecosystem is considered stable or robust if it returns to its original state after a perturbation, exhibits low temporal variability, or does not change dramatically in the face of a perturbation.

Elasticity: A measure of responsiveness of one variable to a change in another, usually defined in terms of percentage change. For example, own-price elasticity of demand is the percentage change in the quantity demanded of a good for a 1% change in the price of that good. Other common elasticity measures include supply and income elasticity.

Emergent disease: Diseases that have recently increased in incidence, impact, or geographic range; that are caused by pathogens that have recently evolved; that are newly discovered; or that have recently changed their clinical presentation.

Emergent property: A phenomenon that is not evident in the constituent parts of a system but that appears when they interact in the system as a whole.

Enabling conditions: Critical preconditions for success of responses, including political, institutional, social, economic, and ecological factors.

Endangered species: Species that face a very high risk of extinction in the wild. See also *Threatened species*.

Endemic (in ecology): A species or higher taxonomic unit found only within a specific area.

Endemic (in health): The constant presence of a disease or infectious agent within a given geographic area or population group; may also refer to the usual prevalence of a given disease within such area or group.

Endemism: The fraction of species that is endemic relative to the total number of species found in a specific area.

Epistemology: The theory of knowledge, or a ''way of knowing.''

Equity: Fairness of rights, distribution, and access. Depending on context, this can refer to resources, services, or power.

Eutrophication: The increase in additions of nutrients to freshwater or marine systems, which leads to increases in plant growth and often to undesirable changes in ecosystem structure and function.

Evapotranspiration: See *Transpiration*.

Existence value: The value that individuals place on knowing that a resource exists, even if they never use that resource (also sometimes known as conservation value or passive use value).

Exotic species: See *Alien species*.

Externality: A consequence of an action that affects someone other than the agent undertaking that action and for which the agent is neither compensated nor penalized through the markets. Externalities can be positive or negative.

Feedback: See *Negative feedback, Positive feedback,* and *Cross-scale feedback*.

Fishery: A particular kind of fishing activity, e.g., a trawl fishery, or a particular species targeted, e.g., a cod fishery or salmon fishery.

Fish stock: See *Stock*.

Fixed nitrogen: See *Reactive nitrogen*.

Flyway: Areas of the world used by migratory birds in moving between breeding and wintering grounds.

Forest systems: Systems in which trees are the predominant life forms. Statistics reported in this assessment are based on areas that are dominated by trees (perennial woody plants taller than five meters at maturity), where the tree crown cover exceeds 10%, and where the area is more than 0.5 hectares. ''Open forests'' have a canopy cover between 10% and 40%, and ''closed forests'' a canopy cover of more than 40%. ''Fragmented forests'' refer to mosaics of forest patches and non-forest land. See also *System*.

Freedom: The range of options a person has in deciding the kind of life to lead.

Functional diversity: The value, range, and relative abundance of traits present in the organisms in an ecological community.

Functional redundancy (= functional compensation): A characteristic of ecosystems in which more than one species in the system can carry out a particular process. Redundancy may be total or partial—that is, a species may not be able to completely replace the other species or it may compensate only some of the processes in which the other species are involved.

Functional types (= functional groups = guilds): Groups of organisms that respond to the environment or affect ecosystem processes in a similar way. Examples of plant functional types include nitrogen-fixer versus non-fixer, stress-tolerant versus ruderal versus competitor, resprouter versus seeder, deciduous versus evergreen. Examples of animal functional types include granivorous versus fleshy-fruit eater, nocturnal versus diurnal predator, browser versus grazer.

Geographic information system: A computerized system organizing data sets through a geographical referencing of all data included in its collections.

Globalization: The increasing integration of economies and societies around the world, particularly through trade and financial flows, and the transfer of culture and technology.

Global scale: The geographical realm encompassing all of Earth.

Governance: The process of regulating human behavior in accordance with shared objectives. The term includes both governmental and nongovernmental mechanisms.

Health, human: A state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity. The health of a whole community or population is reflected in measurements of disease incidence and prevalence, age-specific death rates, and life expectancy.

High seas: The area outside of national jurisdiction, i.e., beyond each nation's Exclusive Economic Zone or other territorial waters.

Human well-being: See *Well-being*.

Income poverty: See *Poverty*.

Indicator: Information based on measured data used to represent a particular attribute, characteristic, or property of a system.

Indigenous knowledge (or local knowledge): The knowledge that is unique to a given culture or society.

Indirect interaction: Those interactions among species in which a species, through direct interaction with another species or modification of resources, alters the abundance of a third species with which it is not directly interacting. Indirect interactions can be trophic or nontrophic in nature.

Indirect use value: The benefits derived from the goods and services provided by an ecosystem that are used indirectly by an economic agent. For example, an agent at some distance from an ecosystem may derive benefits from drinking water that has been purified as it passed through the ecosystem. (Compare *Direct use value*.)

Infant mortality rate: Number of deaths of infants aged 0–12 months divided by the number of live births.

Inland water systems: Permanent water bodies other than salt-water systems on the coast, seas and oceans. Includes rivers, lakes, reservoirs wetlands and inland saline lakes and marshes. See also *System*.

Institutions: The rules that guide how people within societies live, work, and interact with each other. Formal institutions are written or codified rules. Examples of formal institutions would be the constitution, the judiciary laws, the organized market, and property rights. Informal institutions are rules governed by social and behavioral norms of the society, family, or community. Also referred to as organizations.

Integrated coastal zone management: Approaches that integrate economic, social, and ecological perspectives for the management of coastal resources and areas.

Integrated conservation and development projects: Initiatives that aim to link biodiversity conservation and development.

Integrated pest management: Any practices that attempt to capitalize on natural processes that reduce pest abundance. Sometimes used to refer to monitoring programs where farmers apply pesticides to improve economic efficiency (reducing application rates and improving profitability).

Integrated responses: Responses that address degradation of ecosystem services across a number of systems simultaneously or that also explicitly include objectives to enhance human well-being.

Integrated river basin management: Integration of water planning and management with environmental, social, and economic development concerns, with an explicit objective of improving human welfare.

Interventions: See *Responses*.

Intrinsic value: The value of someone or something in and for itself, irrespective of its utility for people.

Invasibility: Intrinsic susceptibility of an ecosystem to be invaded by an alien species.

Invasive alien species: An alien species whose establishment and spread modifies ecosystems, habitats, or species.

Irreversibility: The quality of being impossible or difficult to return to, or to restore to, a former condition. See also *Option value, Precautionary principle, Resilience,* and *Threshold*.

Island systems: Lands isolated by surrounding water, with a high proportion of coast to hinterland. The degree of isolation from the mainland in both natural and social aspects is accounted by the *isola effect*. See also *System*.

Isola effect: Environmental issues that are unique to island systems. This uniqueness takes into account the physical seclusion of islands as isolated pieces of land exposed to marine or climatic disturbances with a more limited access to space, products, and services when compared with most continental areas, but also includes subjective issues such as the perceptions and attitudes of islanders themselves.

Keystone species: A species whose impact on the community is disproportionately large relative to its abundance. Effects can be produced by consumption (trophic interactions), competition, mutualism, dispersal, pollination, disease, or habitat modification (nontrophic interactions).

Land cover: The physical coverage of land, usually expressed in terms of vegetation cover or lack of it. Related to, but not synonymous with, *land use*.

Landscape: An area of land that contains a mosaic of ecosystems, including human-dominated ecosystems. The term cultural landscape is often used when referring to landscapes containing significant human populations or in which there has been significant human influence on the land.

Landscape unit: A portion of relatively homogenous land cover within the local-to-regional landscape.

Land use: The human use of a piece of land for a certain purpose (such as irrigated agriculture or recreation). Influenced by, but not synonymous with, *land cover*.

Length of growing period: The total number of days in a year during which rainfall exceeds one half of potential evapotranspiration. For boreal and temperate zone, growing season is usually defined as a number of days with the average daily temperature that exceeds a definite threshold, such as 10° Celsius.

Local knowledge: See *Indigenous knowledge*.

Mainstreaming: Incorporating a specific concern, e.g. sustainable use of ecosystems, into policies and actions.

Malnutrition: A state of bad nourishment. Malnutrition refers both to undernutrition and overnutrition, as well as to conditions arising from dietary imbalances leading to diet-related noncommunicable diseases.

Marginal abatement cost: The cost of abating an incremental unit of, for instance, a pollutant.

Marine system: Marine waters from the low-water mark to the high seas that support marine capture fisheries, as well as deepwater (>50 meters) habitats. Four sub-divisions (marine biomes) are recognized: the coastal boundary zone; trade-winds; westerlies; and polar.

Market-based instruments: Mechanisms that create a market for ecosystem services in order to improving the efficiency in the way the service is used. The term is used for mechanisms that create new markets, but also for responses such as taxes, subsidies, or regulations that affect existing markets.

Market failure: The inability of a market to capture the correct values of ecosystem services.

Mitigation: An anthropogenic intervention to reduce negative or unsustainable uses of ecosystems or to enhance sustainable practices.

Mountain system: High-altitude (greater than 2,500 meters) areas and steep mid-altitude (1,000 meters at the equator, decreasing to sea level where alpine life zones meet polar life zones at high latitudes) areas, excluding large plateaus.

Negative feedback: Feedback that has a net effect of dampening perturbation.

Net primary productivity: See *Production, biological*.

Non-linearity: A relationship or process in which a small change in the value of a driver (i.e., an independent variable) produces an disproportionate change in the outcome (i.e., the dependent variable). Relationships where there is a sudden discontinuity or change in rate are sometimes referred to as abrupt and often form the basis of thresholds. In loose terms, they may lead to unexpected outcomes or "surprises."

Nutrient cycling: The processes by which elements are extracted from their mineral, aquatic, or atmospheric sources or recycled from their organic forms, converting them to the ionic form in which biotic uptake occurs and ultimately returning them to the atmosphere, water, or soil.

Nutrients: The approximately 20 chemical elements known to be essential for the growth of living organisms, including nitrogen, sulfur, phosphorus, and carbon.

Open access resource: A good or service over which no property rights are recognized.

Opportunity cost: The benefits forgone by undertaking one activity instead of another.

Option value: The value of preserving the option to use services in the future either by oneself (option value) or by others or heirs (bequest value). Quasi-option value represents the value of avoiding irreversible decisions until new information reveals whether certain ecosystem services have values society is not currently aware of.

Organic farming: Crop and livestock production systems that do not make use of synthetic fertilizers, pesticides, or herbicides. May also include restrictions on the use of transgenic crops (genetically modified organisms).

Pastoralism, pastoral system: The use of domestic animals as a primary means for obtaining resources from habitats.

Perturbation: An imposed movement of a system away from its current state.

Polar system: Treeless lands at high latitudes. Includes Arctic and Antarctic areas, where the polar system merges with the northern boreal forest and the Southern Ocean respectively. See also *System*.

Policy failure: A situation in which government policies create inefficiencies in the use of goods and services.

Policy-maker: A person with power to influence or determine policies and practices at an international, national, regional, or local level.

Pollination: A process in the sexual phase of reproduction in some plants caused by the transportation of pollen. In the context of ecosystem services, pollination generally refers to animal-assisted pollination, such as that done by bees, rather than wind pollination.

Population, biological: A group of individuals of the same species, occupying a defined area, and usually isolated to some degree from other similar groups. Populations can be relatively reproductively isolated and adapted to local environments.

Population, human: A collection of living people in a given area. (Compare *Community (human, local)*.)

Positive feedback: Feedback that has a net effect of amplifying perturbation.

Poverty: The pronounced deprivation of well-being. Income poverty refers to a particular formulation expressed solely in terms of per capita or household income.

Precautionary principle: The management concept stating that in cases ''where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation,'' as defined in the Rio Declaration.

Prediction (or forecast): The result of an attempt to produce a most likely description or estimate of the actual evolution of a variable or system in the future. See also *Projection* and *Scenario*.

Primary production: See *Production, biological*.

Private costs and benefits: Costs and benefits directly felt by individual economic agents or groups as seen from their perspective. (Externalities imposed on others are ignored.) Costs and benefits are valued at the prices actually paid or received by the group, even if these prices are highly distorted. Sometimes termed ''financial'' costs and benefits. (Compare *Social costs and benefits*.)

Probability distribution: A distribution that shows all the values that a random variable can take and the likelihood that each will occur.

Production, biological: Rate of biomass produced by an ecosystem, generally expressed as biomass produced per unit of time per unit of surface or volume. Net primary productivity is defined as the energy fixed by plants minus their respiration.

Production, economic: Output of a system.

Productivity, biological: See *Production, biological*.

Productivity, economic: Capacity of a system to produce high levels of output or responsiveness of the output of a system to inputs.

Projection: A potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Projections are distinguished from ''predictions'' in order to emphasize that projections involve assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized; they are therefore subject to substantial uncertainty.

Property rights: The right to specific uses, perhaps including exchange in a market, of ecosystems and their services.

Provisioning services: The products obtained from ecosystems, including, for example, genetic resources, food and fiber, and fresh water.

Public good: A good or service in which the benefit received by any one party does not diminish the availability of the benefits to others, and where access to the good cannot be restricted.

Reactive nitrogen (or fixed nitrogen): The forms of nitrogen that are generally available to organisms, such as ammonia, nitrate, and organic nitrogen. Nitrogen gas (or dinitrogen), which is the major component of the atmosphere, is inert to most organisms.

Realm: Used to describe the three major types of ecosystems on earth: terrestrial, freshwater, and marine. Differs fundamentally from *biogeographic realm*.

Reforestation: Planting of forests on lands that have previously contained forest but have since been converted to some other use. (Compare *Afforestation*.)

Regime shift: A rapid reorganization of an ecosystem from one relatively stable state to another.

Regulating services: The benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases.

Relative abundance: See *Abundance*.

Reporting unit: The spatial or temporal unit at which assessment or analysis findings are reported. In an assessment, these units are chosen to maximize policy relevance or relevance to the public and thus may differ from those upon which the analyses were conducted (e.g., analyses conducted on mapped ecosystems can be reported on administrative units). See also *System*.

Resilience: The level of disturbance that an ecosystem can undergo without crossing a threshold to a situation with different structure or outputs. Resilience depends on ecological dynamics as well as the organizational and institutional capacity to understand, manage, and respond to these dynamics.

Resistance: The capacity of an ecosystem to withstand the impacts of drivers without displacement from its present state.

Responses: Human actions, including policies, strategies, and interventions, to address specific issues, needs, opportunities, or problems. In the context of ecosystem management, responses may be of legal, technical, institutional, economic, and behavioral nature and may operate at various spatial and time scales.

Riparian: Something related to, living on, or located at the banks of a watercourse, usually a river or stream.

Safe minimum standard: A decision analytical framework in which the benefits of ecosystem services are assumed to be incalculable and should be preserved unless the costs of doing so rise to an intolerable level, thus shifting the burden of proof to those who would convert them.

Salinization: The buildup of salts in soils.

Scale: The measurable dimensions of phenomena or observations. Expressed in physical units, such as meters, years, population size, or quantities moved or exchanged. In observation, scale determines the relative fineness and coarseness of different detail and the selectivity among patterns these data may form.

Scenario: A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technology change, prices) and relationships. Scenarios are neither predictions nor projections and sometimes may be based on a ''narrative storyline.'' Scenarios may include projections but are often based on additional information from other sources.

Security: Access to resources, safety, and the ability to live in a predictable and controllable environment.

Service: See *Ecosystem services*.

Social costs and benefits: Costs and benefits as seen from the perspective of society as a whole. These differ from private costs and benefits in being more inclusive (all costs and benefits borne by some member of society are taken into account) and in being valued at social opportunity cost rather than market prices, where these differ. Sometimes termed ''economic'' costs and benefits. (Compare *Private costs and benefits*.)

Social incentives: Measures that lower transaction costs by facilitating trust-building and learning as well as rewarding collaboration and conflict resolution. Social incentives are often provided by bridging organizations.

Socioecological system: An ecosystem, the management of this ecosystem by actors and organizations, and the rules, social norms, and conventions underlying this management. (Compare *System*.)

Soft law: Non-legally binding instruments, such as guidelines, standards, criteria, codes of practice, resolutions, and principles or declarations, that states establish to implement national laws.

Soil fertility: The potential of the soil to supply nutrient elements in the quantity, form, and proportion required to support optimum plant growth. See also *Nutrients*.

Speciation: The formation of new species.

Species: An interbreeding group of organisms that is reproductively isolated from all other organisms, although there are many partial exceptions to this rule in particular taxa. Operationally, the term *species* is a generally agreed fundamental taxonomic unit, based on morphological or genetic similarity, that once described and accepted is associated with a unique scientific name.

Species diversity: Biodiversity at the species level, often combining aspects of species richness, their relative abundance, and their dissimilarity.

Species richness: The number of species within a given sample, community, or area.

Statistical variation: Variability in data due to error in measurement, error in sampling, or variation in the measured quantity itself.

Stock (in fisheries): The population or biomass of a fishery resource. Such stocks are usually identified by their location. They can be, but are not always, genetically discrete from other stocks.

Stoichiometry, ecological: The relatively constant proportions of the different nutrients in plant or animal biomass that set constraints on production. Nutrients only available in lower proportions are likely to limit growth.

Storyline: A narrative description of a scenario, which highlights its main features and the relationships between the scenario's driving forces and its main features.

Strategies: See *Responses*.

Streamflow: The quantity of water flowing in a watercourse.

Subsidiarity, principle of: The notion of devolving decision-making authority to the lowest appropriate level.

Subsidy: Transfer of resources to an entity, which either reduces the operating costs or increases the revenues of such entity for the purpose of achieving some objective.

Subsistence: An activity in which the output is mostly for the use of the individual person doing it, or their family, and which is a significant component of their livelihood.

Subspecies: A population that is distinct from, and partially reproductively isolated from, other populations of a species but that has not yet diverged sufficiently that interbreeding is impossible.

Supporting services: Ecosystem services that are necessary for the production of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat.

Sustainability: A characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generations or populations in other locations to meet their needs.

Sustainable use (of an ecosystem): Human use of an ecosystem so that it may yield a continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations.

Symbiosis: Close and usually obligatory relationship between two organisms of different species, not necessarily to their mutual benefit.

Synergy: When the combined effect of several forces operating is greater than the sum of the separate effects of the forces.

System: In the Millennium Ecosystem Assessment, reporting units that are ecosystem-based but at a level of aggregation far higher than that usually applied to ecosystems. Thus the system includes many component ecosystems, some of which may not strongly interact with each other, that may be spatially separate, or that may be of a different type to the ecosystems that constitute the majority, or matrix, of the system overall. The system includes the social and economic systems that have an impact on and are affected by the ecosystems included within it. For example, the Condition and Trend Working Group refers to ''forest systems,'' ''cultivated systems,'' ''mountain systems,'' and so on. Systems thus defined are not mutually exclusive, and are permitted to overlap spatially or conceptually. For instance, the ''cultivated system'' may include areas of ''dryland system'' and vice versa.

Taxon (pl. taxa): The named classification unit to which individuals or sets of species are assigned. Higher taxa are those above the species level. For example, the common mouse, *Mus musculus,* belongs to the Genus *Mus,* the Family Muridae, and the Class Mammalia.

Taxonomy: A system of nested categories (*taxa*) reflecting evolutionary relationships or morphological similarity.

Tenure: See *Property rights,* although also sometimes used more specifically in reference to the temporal dimensions and security of property rights.

Threatened species: Species that face a high (*vulnerable species*), very high (*endangered species*), or extremely high (*critically endangered species*) risk of extinction in the wild.

Threshold: A point or level at which new properties emerge in an ecological, economic, or other system, invalidating predictions based on mathematical relationships that apply at lower levels. For example, species diversity of a landscape may decline steadily with increasing habitat degradation to a certain point, then fall sharply after a critical threshold of degradation is reached. Human behavior, especially at group levels, sometimes exhibits threshold effects. Thresholds at which irreversible changes occur are especially of concern to decision-makers. (Compare *Non-linearity*.)

Time series data: A set of data that expresses a particular variable measured over time.

Total economic value framework: A widely used framework to disaggregate the components of utilitarian value, including *direct use value, indirect use value, option value,* quasi-option value, and *existence value*.

Total factor productivity: A measure of the aggregate increase in efficiency of use of inputs. TFP is the ratio of the quantity of output divided by an index of the amount of inputs used. A common input index uses as weights the share of the input in the total cost of production.

Total fertility rate: The number of children a woman would give birth to if through her lifetime she experienced the set of age-specific fertility rates currently observed. Since age-specific rates generally change over time, TFR does not in general give the actual number of births a woman alive today can be expected to have. Rather, it is a synthetic index meant to measure age-specific birth rates in a given year.

Trade-off: Management choices that intentionally or otherwise change the type, magnitude, and relative mix of services provided by ecosystems.

Traditional ecological knowledge: The cumulative body of knowledge, practices, and beliefs evolved by adaptive processes and handed down through generations. TEK may or may not be indigenous or local, but it is distinguished by the way in which it is acquired and used, through the social process of learning and sharing knowledge. (Compare *Indigenous knowledge*.)

Traditional knowledge: See *Traditional ecological knowledge*.

Traditional use: Exploitation of natural resources by indigenous users or by nonindigenous residents using traditional methods. Local use refers to exploitation by local residents.

Transpiration: The process by which water is drawn through plants and returned to the air as water vapor. Evapotranspiration is combined loss of water to the atmosphere via the processes of evaporation and transpiration.

Travel cost methods: Economic valuation techniques that use observed costs to travel to a destination to derive demand functions for that destination.

Trend: A pattern of change over time, over and above short-term fluctuations.

Trophic cascade: A chain reaction of top-down interactions across multiple tropic levels. These occur when changes in the presence or absence (or shifts in abundance) of a top predator alter the production at several lower trophic levels. Such positive indirect effects of top predators on lower tropic levels are mediated by the consumption of mid-level consumers (generally herbivores).

Trophic level: The average level of an organism within a food web, with plants having a trophic level of 1, herbivores 2, first-order carnivores 3, and so on.

Umbrella species: Species that have either large habitat needs or other requirements whose conservation results in many other species being conserved at the ecosystem or landscape level.

Uncertainty: An expression of the degree to which a future condition (e.g., of an ecosystem) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined terminology or uncertain projections of human behavior. Uncertainty can therefore be represented by quantitative measures (e.g., a range of values calculated by various models) or by qualitative statements (e.g., reflecting the judgment of a team of experts).

Urbanization: An increase in the proportion of the population living in urban areas.

Urban systems: Built environments with a high human population density. Operationally defined as human settlements with a minimum population density commonly in the range of 400 to 1,000 persons per square kilometer, minimum size of typically between 1,000 and 5,000 people, and maximum agricultural employment usually in the vicinity of 50–75%. See also *System*.

Utility: In economics, the measure of the degree of satisfaction or happiness of a person.

Valuation: The process of expressing a value for a particular good or service in a certain context (e.g., of decision-making) usually in terms of something that can be counted, often money, but also through methods and measures from other disciplines (sociology, ecology, and so on). See also *Value*.

Value: The contribution of an action or object to user-specified goals, objectives, or conditions. (Compare *Valuation*.)

Value systems: Norms and precepts that guide human judgment and action.

Voluntary measures: Measures that are adopted by firms or other actors in the absence of government mandates.

Vulnerability: Exposure to contingencies and stress, and the difficulty in coping with them. Three major dimensions of vulnerability are involved: exposure to stresses, perturbations, and shocks; the sensitivity of people, places, ecosystems, and species to the stress or perturbation, including their capacity to anticipate and cope with the stress; and the resilience of the exposed people, places, ecosystems, and species in terms of their capacity to absorb shocks and perturbations while maintaining function.

Vulnerable species: Species that face a high risk of extinction in the wild. See also *Threatened species*.

Water scarcity: A water supply that limits food production, human health, and economic development. Severe scarcity is taken to be equivalent to 1,000 cubic meters per year per person or greater than 40% use relative to supply.

Watershed (also catchment basin): The land area that drains into a particular watercourse or body of water. Sometimes used to describe the dividing line of high ground between two catchment basins.

Water stress: See *Water scarcity*.

Well-being: A context- and situation-dependent state, comprising basic material for a good life, freedom and choice, health and bodily well-being, good social relations, security, peace of mind, and spiritual experience.

Wetlands: Areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters. May incorporate riparian and coastal zones adjacent to the wetlands and islands or bodies of marine water deeper than six meters at low tide laying within the wetlands.

Wise use (of an ecosystem): Sustainable utilization for the benefit of humankind in a way compatible with the maintenance of the natural properties of the ecosystem

Index

Italic page numbers refer to figures, tables, and boxes. Bold page numbers refer to the Summary.

A

Abandonment of agricultural lands, 159–160
Adaptation of MA conceptual framework across scales, **11,** ***12,*** 31, 72–73, *73,* 280, 284–285. *See also specific assessments*
  knowledge systems and, 108–109
Adapting Mosaic scenario, 257–258
Adaptive co-management approach, **7,** 77, 109, 167–169, 275–276
Adaptive renewal model, *73*
Advisory committees. *See* Stakeholders in sub-global assessments
Agriculture
  crop and land use changes, **9,** 82, 96
  ecological problems confronting, 17
  land use and, 144
  smallholder agriculture, 158–160, *159*
Air pollution, 145, 182, 191
Alaska assessment, 311
Altai-Sayan Ecoregion assessment, *298, 312,* 312–313
  climate-related extreme events, 150, 163
  condition and trends of ecosystem services, 179
  market system, **5,** 158
  reporting categories, 199
  traditional knowledge and biodiversity, 96
Alternatives to Slash-and-Burn (ASB) matrix and program, 196–197, *198,* 217
Amazon. *See* Tropical Forest Margins assessment
Annan, Kofi, 16
Arafura and Timor Seas assessment, 314
Argentine Pampas assessment, 164, 176, 315
ASB (Alternatives to Slash-and-Burn) matrix and program, 196–197, *198,* 217
Assessment methods of MA, 25–26
Assessment process of sub-global assessments. *See* Sub-global assessments
Associated sub-global assessments, 33–34, *39–41*
Australia. *See* Northern Australian Floodplains assessment

B

Bajo Chirripó, Costa Rica, assessment, 329
  collaborative participation of stakeholders, 98
  crop diversity as hedge against disaster, **9**
  exchange with Vilcanota assessment, *138*
  funding, 127
  human well-being and, *49,* 272
  indigenous perspective on well-being, 76
  institutions lacking to implement management plans, 129
  local/traditional knowledge as component of, 93, *99,* 107, 108, 110, 114
  locally led assessment, 285
  MA conceptual framework and, 108, 132–133
  religious and spiritual beliefs, 194
  scenario-building, **7,** *245,* 253
  spatial heterogeneity, 178
Benefits-costs analysis. *See* Costs and benefits
Biodiversity, 182–194
  assessment of, 173
    availability of data for, 180
  climate change and, 182, 253
  condition and trends, 184–185, *202–203*
    compared to remaining native habitat, *295*
    indicators of, 183–184, *184*
    inventories, 175, 183
  drivers of change for, 182–183
  ecosystem services and, 19
  human well-being and, 45
  invasive species. *See* Invasive species
  multiscale assessment, **10,** 80, *81*
  scenario-building and, 253, *253*
  substitutions, feasibility of, 22
  trade-off with land use, 196
Biodiversity Intactness Index, *81,* 184, *184*
Biological drivers, 150–151, 153
Biological invasions. *See* Invasive species
Boundary organizations, 91
Brazil. *See* São Paulo Greenbelt assessment
"Bridging Scales and Epistemologies: Linking Local Knowledge and Global Science in Multiscale Assessments" (Alexandria, Egypt, 2004), 88–89, 92–93, 104, 286, 287
British Columbia. *See* Coastal British Columbia, Canada (Coastal BC assessment)

C

Capacity-building activities, 77–78, 121, 137
  as purpose of sub-global assessments, **2,** 32
  for future assessments, **14,** 133, *134*
  multiscale assessments providing greater opportunity for, 68
  necessary component of assessment, **11,** 282–283
Carbon sequestration, 53, 191
Caribbean Sea assessment, *301, 318,* 318–319
  biodiversity, 253
  climate-related extreme events, 150–151, 164
  data availability to assess ecosystem services, *179*
  drinking water, 52
  environment and resource education, 139
  fishing industry, importance of, 51, 52, 148, 190
  indicators of condition and trends, 191
  international cooperation needed to rebuild fish stocks, 129, 148
  international management framework, U.N. resolution to create, 76, 127, 211
  invasive species, **5,** 150
  local knowledge not used, 108
  marine animal catches by type, *296*
  scenario-building, **7,** *242,* 245, *245,* 254
  sea urchin fishery in St. Lucia, *214*
  time frame for, 178, 179
  tourism, 54, 162
  user group involvement, 126
CBD. *See* Convention on Biological Diversity
Central Asia Mountain Ecosystems assessment, 320
Chile. *See* San Pedro de Atacama assessment
China. *See* Western China assessment
Climate change, **5**
  across scales, **9,** 80
  as driver of change, 77, 143, 144–145, 150–151, 157
  biodiversity and, 182, 253
Coastal British Columbia, Canada (Coastal BC assessment), 321–322
  climate events, 164
  Ecological Integrity Index, 47, 184, *186*
  fishing industry, 77, 160
  indicators of condition and trends, 190–191
  introduction of new species, 150
  knowledge practitioners' role, 97
  land use change, 165
  local/traditional knowledge vs. science, 102, 107, 108
  MA conceptual framework and, 109
  mapping techniques and scenario-building, 150
  user group involvement, 126
Coffee, ***9,*** 53, 82, 148, 183, *299*
Collaboration among actors, **7–8,** 215–218
  "bridging organizations" facilitating, 207, 216–218, *218*
  dynamic nature of responses and, 214
  interplay of formal and informal institutions, 215–216
  local communities included in, 262
Colombia assessment, ***9,*** 82, 199, *299, 323,* 323–324
Communication
  in scenario-building, **7,** 250–252, *251*
  strategy, 136–139, *292*
Community assessments. *See* Local communities

Conceptual framework of ecosystem assessment, 16–27, *20*
adaptation and modification made for sub-global assessments, **11,** ***12,*** 31, 72–73, *73,* 280, 284–285
assessment tools, 25–26
community assessments and, 268, 270
cross-scale interactions and, 23–24, 285
drivers of change and, 23, 145–146
ecosystems and their services, 19–22
human well-being as focus of, 19, 283–284
knowledge systems not adequately covered in, 113–114
multiscale approach. *See* Multiscale assessments
poverty and, 22–23
reporting categories used in, *21,* 199
spatial and temporal scales. *See* Spatial scales; Temporal issues
statement of problem, 17–19
strategies and interventions, 26–27
utility of, **11,** 108–109, 280, 283–385
values associated with ecosystems, 24–25, *25*
Condition and trends of ecosystem services, 174–181
assessment approaches for, 174–176
biodiversity, 184–185, *202–203*
challenges in assessing, 176–182
cultural services, 192–194, *202–203*
defining and assessing, 176–178
ecological models, 175–176
economic valuation, 176
fluctuations in time, 179–180
geographic information systems (GIS), 174
indicators of, 174–175
biodiversity, 183–184, *184*
cultural services, 191–192
provisioning services, 188–189
regulating services, 190–191
supporting services, 187
inventories, 175, *175*
participatory approaches and expert opinion, 176, *176*
provisioning services, 189–190, *202–203*
regulating services, 191, *202–203*
remote sensing, 174
supporting services, 187–188, *202–203*
Conflict and loss of ecosystem services, 58
Conservation status analysis, 184, *185*
Convention on Biological Diversity (CBD)
definition of diversity, 182
ecosystem approach endorsed by, 19
Convention on Migratory Species, 16
Convention to Combat Desertification, 16
Costa Rica. *See* Bajo Chirripó, Costa Rica, assessment
Costs and benefits
inequities of ecosystem change, **4–5**
of multiscale assessments, 74–78
Crises in ecosystems, 166, *167*
Cross-scale interactions, 23–24, 285
between science and local/traditional knowledge, 107
defined, 64–65
drivers of change and, 157–158
economic incentives and, 219
improved analysis of, 67, 75–76
local communities and, 266, 274–275
scenario-building and, 245–247, *254,* 254–255
Cultural and religious drivers, 150
Cultural services, 54, 191–194
assessment of, as novel feature in MA framework, 283–284
availability of data for assessment, 180, 284
condition and trends, 192–194, *202–203*
defined, 19
drivers of change for, 191
importance to local communities, **3,** *193,* 193–194, 262, 272–273
indicators of condition and trends, 191–192
local/traditional knowledge. *See* Knowledge systems

D

Data collection and validation at local level, 123, 266–268, 282
Decision-making process
drivers of change and, 23, 146
MA design and, **2,** 122–123
public participation in, 22
strategies and interventions in, 26–27
trade-offs and, 195–198
Deforestation, ***4, 6,*** **9,** 159
carbon sequestration and, 53
flooding and, 53, 190
infectious disease and, 54
provisioning services and, 188
watershed disruption caused by, 219
Demographic drivers, 144, *144,* 147–148, *149*
population resettlement programs, 160–161
Design of Millennium Ecosystem Assessment (MA), *31,* 31–32
capacity-building objective of, 32, 68
decision-making process and, **2,** 122–123
engagement of users, 32
innovative features of sub-global design, 32, *79,* 80, 281, 288–289
knowledge systems in, 102–111. *See also* Knowledge systems
lessons learned for, 288–289
multiscale assessments and, 31–32, 68–69, *69–71,* 72
Direct drivers. *See* Drivers of change
Diversity. *See also* Biodiversity
enhancing effectiveness of response options, **8,** 207
in knowledge systems, **11,** 31, 87
in reducing vulnerability of ecosystem services, **8–9**
scenario-building and, 255
of stakeholders. *See* Stakeholders in sub-global assessments
within and among local communities, 262, 265–266
Downstream Mekong River Wetlands assessment (Viet Nam), 359
biodiversity conditions, 274
cross-scale interactions, 157
invasive species, 182
inventory of ecosystem services, *175*
lifestyle changes, 150, 159, 194
population increase and demand for food, 158–159
trade-offs between ecosystem services and human well-being, **3,** 57
water flow regulation, 53–54
Drivers of change, **5,** 23, 141–169, 284. *See also specific drivers*
adaptive co-management of social-ecological systems, 167–169
anthropogenic drivers, 152, 153, 190
assessment of, 134, 157
for biodiversity, 182–183
categories of, 146, 147–151, 284
spatial scales and, 151–155
climate change. *See* Climate change
constraining of, **6,** 164, 166–167
control of, 143, 284
crises in ecosystems, *167*
cross-scale impacts of, 157–158
cultural and religious drivers, 150
for cultural services, 191
defined, 23
deforestation, **6,** 76, 159
demographic drivers, 144, *144,* 147–148, *149*
direct drivers, 23, 145, *152–156,* 153
economic drivers, 148, 153, 160–161, *161*
emerging patterns, 153–155
endogenous drivers, 146, 151, *152–156,* 284
exogenous drivers, 146, 151, *152–156,* 214, 284
global scale and, 152–153
"trickle-down" to local scale, 157, *158*
global trends and, *144,* 144–145
implications for interventions, 166–169, *168*
indirect drivers, **5,** 23, 143, 145, *152–156,* 154, 156, *293*
integrating, 157–164
assessment process, 157
responses addressing, 207
interactions among, **5–6,** 23, 143, 158–164
global loops, 160
intervention in, 167, *168*
local loops, 160, *161*
major processes of, *165*
patterns of interaction, 164
responses addressing, 207
invasive species. *See* Invasive species
land use. *See* Land use change
lessons learned, 284
local scale and, 151, *152*
methods used to identify and assess in sub-global assessments, 146–147, *147,* 284
lack of information for, 146
scientific perspective in, *148*
multiple effects of interventions, 166–167, *168*
national scale and, 151–152, *154*
"trickle-down" to local scale, 157, *158*
partial control of decision-makers, 146, 151
physical and biological drivers, 150–151, 153
pollution. *See* Pollution
for provisioning services, 188
regional differences in effects of, **6,** 143
regional scale and, 152, *155*
for regulating services, 190
reinforcement of, **5–6,** 164, 166

responses addressing, 135, 207
science and technology, 149–150
smallholder agriculture, 158–160, *159*
sociopolitical drivers, 148–149
spatial and temporal scales of, **6,** 143, 146, 151–155
dynamics of, 155–157, *157*
multiscale issues, 167, 214
relationship of, *156*
speed of, 156–157, *157*
sub-national scale and, 151, *153*
for supporting services, 187
thresholds and, 164–166
tourism, 148, 162–163, *163*
triggering of, **5–6,** 164, 166
within MA conceptual framework, 23, 145–146

E

Eastern Himalayas assessment, *300, 325,* 325–326
deforestation, **9,** 159, 160
external processes' effect, 274
infrastructure development, 161
local knowledge, 96, 108, 111
Ecological Integrity Index, 47, 184, *186*
Economic growth as indirect driver of change, **5,** 148, 160–161, *161*
Economic incentives. *See* Markets and trade
Economic valuation, 176, *177,* 199
Ecosystem change, responses to. *See* Responses to ecosystem change
Ecosystem degradation, 17, 182
Ecosystem services. *See also* Cultural services; Provisioning services; Regulating services
assessment of, 133–134, 173
availability of data for assessment, 180–181
biodiversity and, 19
in conceptual framework, 19–22
condition and trends. *See* Condition and trends of ecosystem services
cultural and spiritual services. *See* Cultural services
decline of, **5,** 45, 173, 195, 207
defined, *17,* 45–47
effectiveness of assessment, by individual assessment teams, *48*
failure of civilizations and, *46*
importance of, 45
interdependence of, 194–196
linkage with human well-being, **2–5,** *18,* 51–55, 173
assessment of, 133–134, 199
consequences of ignoring, 57–58
long-term monitoring of, need for, 173
provisioning services. *See* Provisioning services
regulating services. *See* Regulating services
regulatory institutions to ensure, 45
supporting services. *See* Supporting services
synthesis of assessment approaches for, 198–200
technology as substitute for, 77, 150
trade-offs of. *See* Trade-offs
values associated with, 24–25, *25*
Ecosystems
boundaries for, 19
defined, *17*
diversity in sub-global assessments, **2,** ***3,*** 256
Ecotourism, 18, 54, 163, 191, *193. See also* Tourism
Educational activities, 194, *268*
Empowerment of local resource users, **10,** 87, 97–101, *98,* 111, 114, 263
Encroachment on natural ecosystems, ***5,*** 148, 159
Endogenous drivers. *See* Drivers of change
Endogenous uncertainties, *237*
Energy output, *144*
Equity issues. *See* Inequities of ecosystem change
Ethical protocol of use of local and traditional knowledge, *92*
Exogenous drivers. *See* Drivers of change
Exogenous uncertainties, *237*
Expert opinion, use of, 176
Exploitation as driver of change, 148, 160, 182
Extinction of local species. *See* Biodiversity
Extraction of natural resources, 160, *161. See also* Logging; Mining
Extreme events. *See* Natural disasters and extreme events

F

Failure of civilizations and ecosystem services, *46*
Fertilizers, application of, 22, 145
Fiji assessment, *300,* 328, *328*
Fires. *See* Natural disasters and extreme events
Fish and fisheries. *See also* Caribbean Sea assessment
as food source, 52
British Columbia and commercialization of fishing, 77
emergency provisions to preserve, 58
exploitation as driver of change, 148, 160
future demand for, 17
Laguna Lake, Philippines, fish production, *180*
Flooding, 53, 190, *192*
Food production. *See also* Provisioning services
increase in grain production, *144*
shortage, 189–190
confirmed in smaller scale assessments, 75, 76
trade-offs and insecurity, 80, 196
Forests. *See also* Deforestation
as indicators of regulating services, 191
carbon dioxide and, 53
cross-scale interactions and, 65
economic valuation of forestry sector in Portugal, *177*
encroachment on, 148, 159
water flow and, 53
Freedom of choice and human well-being, 22
Fresh water. *See* Water resources
Fuelwood, ***4,*** 52–53, 75, *96,* 159, 160, 189
Funding for sub-global assessments, 33, 126–127, *128, 135*
Future assessments, lessons for. *See* Lessons for future assessments

G

Gariep Basin assessment. *See* SAfMA Gariep assessment
Gender differentiation and local/traditional knowledge, 106, 265
Geographic information systems (GIS), 174
Global drivers of change, 152–153
"trickle-down" to local scale, 157, *158*
Global Environment Outlook (UNEP), 64
Global International Waters Assessment, 64
Global Orchestration scenario, 257
Global vs. sub-global analyses, **5**
global forces, local impacts, 80
scenario-building, **7,** 232–234, 247–248, 256
water scarcity, ***6,*** 189, *296*
Globalization
biogeochemical cycles and, 145
effect of, **5,** 82
Glomma and Lägen River Basins, *303*
Governance structure
adjustment needed in, 275
biodiversity and, 182–183
for discussing assessments, **14,** 121, 129–133, *131*
evolution of, 80–81
uncertainty of, 77, 253

H

Habitat loss, 182
Health, human. *See also* Human well-being; Infectious diseases
traditional healing and treatment, 96
Heterogeneity, 178–179, *180,* 185, 247, 286
Hierarchy theory, *79*
Hindu-Kush Himalayas assessment, 55, *301,* 332, *332*
Historical perspective
ecosystem services and local livelihoods, 271–273
for scenarios, ecology overlooked in, 19
HIV/AIDS, 76, 236
Human well-being
as focus of ecosystem assessment, 19, 283
as perceived by selected communities assessed, *49,* 272
components of, 47–51, *49–50*
defined, *17,* 76
equity and access issues, 57
freedom and choice, 22
health, 22, *49, 50*
linkage with ecosystem services, **2–5,** *18,* 51–55, 173
assessment of, 133–134, 199, 283–284
consequences of ignoring, **4,** 57–58
material needs, 22
poverty reduction and, 22–23
provisioning services and. *See* Provisioning services
regulating services and. *See* Regulating services
security and, 22, *49, 50*
trade-offs with ecosystem services, **3,** 55–57, *56*

I

Identity and sense of place
ecosystems providing for local people, **8,** 51, 273
local knowledge and. *See* Knowledge systems
Impact benefits of multiscale assessments, 67–68, 76–78
India. *See also* Eastern Himalayas assessment; India Local Villages (India Local assessment); India Urban Resource (India Urban assessment)
Biodiversity Management Committees in, **8**

India *(continued)*
land use conversion, ***4,*** 195
National Biodiversity Act and local level participation, 211, 253, 264
sacred groves and pools, **3,** 17, 107, 194, 272, 273
India Local Villages (India Local assessment), 333–334
crop diversity as hedge against disaster, **9**
defining condition and trends, 176
failure of projects to improve living conditions, 149
local government participation, 106
local knowledge as component of, 93, 96–97, 101, 103, 108, 110, 114, 264
multiscale management approach of biodiversity, *212*
overfishing, 160
People's Biodiversity Register, 80, 106
religious and cultural sites. *See* India
traditional medicine, 96, 263
India Urban Resource (India Urban assessment), 194, 244–245, *302, 336,* 336–337
Indirect drivers. *See* Drivers of change
Indonesia assessment, 335
Inequities of ecosystem change, **4–5,** 57
Infectious diseases. *See also specific disease*
India, due to deforestation, ***4***
regulation of, 54
waterborne diseases, **4**
Information benefits
of multiple knowledge systems, 93–97
of multiscale assessments, 67, *67,* 75–76
Infrastructure development, 161
Institutional context for implementing policy tools, 207
Institutional responses, 80, 209
Institutions' role
in knowledge systems, **11,** 87, 109–111, *112–113*
in technical work, 132, *132*
Integrated nature of sub-global assessments, **2,** 30
multiple scales used in assessment, **9–11,** 73–74
Integration of local/traditional and scientific knowledge, 92, 107, 264
Intergovernmental Panel on Climate Change (IPCC)
adaptation of procedures for MA process, 102
multiscale analyses of, 66
Third Assessment Report, 64
Interventions
drivers of change and, 166–169, *168*
MA assessment of, 26–27
Invasive species, **5,** 54, 143, 150, 182
IPCC. *See* Intergovernmental Panel on Climate Change

K

Kinship networks, 275
Knowledge systems, **10–11,** 85–117
benefits of using multiple systems, **10, 11,** 31, 87, 93–102
boundary organizations and, 91
challenges in using, 88–89, 103, 113
community knowledge sharing, 268, *269*
cultural identity and, 107
defined, 89
empowerment of local resource users and, **10,** 87, 97–101, *98,* 111, 114
experiential learning and, 110–111
facilitators of, 90
failure to achieve sharing of knowledge as expected, **10–11,** 87
guidelines for inclusion of, 88, 102–103
incorporating multiple knowledge systems in MA process, 103–106, *105*
indigenous knowledge, 90
influence of different knowledge systems, 107–108
information benefits, 93–97
integration of local/traditional and scientific knowledge, 92, 107, 264
interpreters of, 90
lessons learned from, 111–114, 285–286
local and traditional knowledge, contributions of, **10,** 26, 87, 90, 91–92, *94–95,* 263–264, 285–286
ethical protocol of use of, *92*
policies of Sub-global Working Group on, 102, 115
local institutions' role in, **11,** 87, 109–111, *112–113*
MA conceptual framework and, 285–286
methods used to incorporate, *100, 269*
practitioners and participation in assessment, **10,** 90, 97–101
purpose of including multiple knowledge systems, 88
responses to ecosystem change and, 208, 212–213
science, 89–90, 264
use and application of findings, 101–102
Kristianstad Wetlands (Sweden KW assessment), 351–352
adaptive co-management approach, **7,** 109, 168–169, 217
biodiversity condition and trends, 186–187
bottom-up collaboration, *212*
climate change, 150, 157, 163–164
crisis management, *167*
environmental awareness, 150
global and national "trickle-down" to local level, *158*
historical continuity and local knowledge, 96, 108, 110, 111, 114, 273
involvement of stakeholders from different scales, 72, 106
knowledge of participants, 97
policy windows, role of, *211*
scenario-building, *245*
sense of place and identity, **8,** 273
social networks, role of, 274
urban sprawl, 162
Kuznets curve, 56

L

Lack of data as problem
condition and trends assessment, 177, 180–181
for cultural services, 180, 284
methods used to identify and assess in sub-global assessments, 146
Laguna Lake Basin assessment (Philippines), *304,* 344, *344*
adaptive co-management approach, **7,** 77
defining condition and trends, 176, 177
fluctuations in time, 179–180, *180*
global and national "trickle-down" to local level, *158*
interdependence of ecosystem services, 194–195
land use conversion, 157, 191
local knowledge not used, 108
River Rehabilitation Councils, 217
top-down collaboration, *212*
water resources, **5,** 189
Land tenure, intensification in, 159
Land use change, **5,** 143, 199, *297. See also* Agriculture; Deforestation; Urban growth and urbanization
agriculture and, 144
biodiversity, effect on, 173
coffee production and. *See* Coffee
trade-off with biodiversity, 196
Lessons for future assessments, **11–14**
adaptation of MA conceptual framework for some sub-global assessments, **11, *12***
benefits and shortcomings of multiscale assessments, **11–12**
new tools and methodologies for future use, **14,** 80, 280
requirements of sub-global assessments, **12–14, *13,*** 78–80, 133, 289
responses to ecosystem change, 220–221
scenario-building, 255–257
sequence and timing of global and sub-global assessments, 289
shortcomings of multiscale assessments, *79*
Lessons learned, **2–9,** 139–140, 279–289. *See also* Lessons for future assessments
active role of local communities, **8–9,** 262
assessment vs. research, 282
capacity-building, 282–283
collective learning, 282–283
drivers of change, 284
ecosystem services in decline. *See* Ecosystem services
human well-being tied to ecosystems, **2–5.** *See also* Human well-being
knowledge systems, **10,** 111–114, 285–286
local-level assessments, **8–9,** 286–287. *See also* Local communities
MA conceptual framework usefulness on sub-global level, 280, 283–385, 288–289
multiscale assessments, 78–80, 288
networking, 282–283
practical constraints, adaptive solutions, 281
products and outcomes, 287–288
response options, **6–7.** *See also* Responses to ecosystem change
scenario-building, 284
sub-global assessments, 288
trade-offs, 287
users, stakeholders, and reviewers, 282
Livelihoods
avoidance of risks to, 81
clusters at village level, 265
community empowerment and, 263

ecosystem services and, 271–273
local-scale perspective and, 75
sustainable livelihoods framework, *73*
Local communities, 261–277
ability to cope with larger-scale processes, **9,** 262
active role of, **8–9,** 79–80, 262
assessment methods, 265–270
community engagement and benefits, 266, *267*
data collection and validation, 123, 266–268
MA conceptual framework and, 268, 270
typology of community participation and knowledge systems, *269*
collaboration with, **9,** 262
continuous evolution of local management systems, **9,** 273–274
cross-scale interactions, 266, 274–275
cultural and spiritual services, value for, 262
diversity within and among, 262, 265–266
ecosystem services and local livelihoods, 271–273
ecosystem threats reduced by, **8,** 262, 271–272
findings of, 270–275
fluctuations in flow of ecosystem goods and services, sensitivity to, 264
global factors affecting, **9,** 80
global impact of local processes, 82
lessons learned, 275–276, 286–287
rationale for conducting assessments at community level, 263–264
scale of factors affecting, **9**
social networks, role of, 274–275
theoretical background, 264–265
Local knowledge. *See* Knowledge systems
Logging, 160, 165, 178

M

MA. *See* Millennium Ecosystem Assessment
Macroeconomic policy reform, 160
Mapping exercises, *268*
scenario-building and, 150, 252
Markets and trade, 81–82
absence in responses of sub-global assessments, 218
business sector and response options, 207
cross-scale interactions and, 65, 157
global increase, *144,* 145
macroeconomic policy reform, 160
smallholder agriculture and, 158
Mega-projects as drivers of change, 148
Mekong River. *See* Downstream Mekong River Wetlands assessment (Viet Nam)
Millennium Ecosystem Assessment (MA)
assessment tools for, 25–26
conceptual framework. *See* Conceptual framework of ecosystem assessment
design. *See* Design of Millennium Ecosystem Assessment (MA)
reporting categories of, 20, *21*
scenarios in, 232, 257–258
sub-global assessment process in, 32–35
Mining
as driver of change, 148
effect on ecosystem services, 51
effect on surface water, ***5,*** 52
Modeling, 25, *74,* 175–176, 196, 242–243
Mongolia. *See* Altai-Sayan Ecoregion
Morocco, 338
Multiscale assessments, 31, 61–83
aligning assessment and management scales, 74
balance of various approaches in, 68
benefits of, **11–12,** 63, 66–68, 74–78
evaluation of robustness and persistence of findings, **10**
impact benefits, 67–68, 76–78
information benefits, 67, *67,* 75–76
capacity-building and. *See* Capacity-building activities
causality, improved analysis of, 67, 75–76
characterization of, *66*
comprehensive, 63, 65, 67, 69, 72, 76
cost-benefit assessment, 74–78
cross-scale interactions, improved analysis of, 75–76
definitions of terms, 64–66
drivers of change and, 167
impact benefits and costs, 76–78
lessons learned from, **10,** 78–80, 288
MA design and, **2,** 31–32, 68–72, *69–71*
mechanisms for linking scales, 73–74
modeling intermediate scales, *74*
purpose of, **9–11,** 63, 64–68
relevance of assessment findings, **9–10,** 68, 76–77
relevance of problem definition, **9–10,** 68, 76
reliability and accuracy of findings, 67, 76
resource- and time-intensive, **11–12,** 63, 72
scale
considerations, 66
defined, 64, *65*
evolving scale-related issues, 79–80
integrating across different scales, **11–12,** 73–74
level vs., 64
scale-dependent processes, improved analysis of, 67, 75–76
scenarios analysis, benefits of, 77, 245–247
shortcomings of, **11,** 74, *79*
stakeholder involvement and, 63
user ownership and capacity building, 77–78
via analysis, 66

N

Natural disasters and extreme events, 150–151, *163,* 163–164, *167,* 219. *See also* Flooding
Natural resource inventories, 175
Nested design of assessments, **2, *4,* 9,** *72,* 246, *246*
comprehensive multiscale assessment and, 65, 68–69
MA design calling for, *31,* 31–32
scenarios, nesting of, 246
Networking, 274–275, 282–283
New tools and methodologies for future assessment use, **14,** 80, 280
NGO role in assessments, 99, 102, 126, 129, 217
Non-utilitarian value paradigm, 25
Northern Australian Floodplains assessment, 339
Northern Range. *See* Trinidad (Northern Range assessment)
Norway assessment, 127, 185, *340,* 340–341

O

Order from Strength scenario, 257

P

Papua New Guinea (PNG) assessment, *304, 342,* 342–343
assessment initial stages involving multiple users, *125*
climate change, 150, 164
crop diversity as hedge against disaster, **9**
ecosystem diversity as benefit, 271
fishing industry, importance of, 52, 148, 160
funding, 127
key uncertainties, 236
local community subject to national and international conservation, 274
logging, 160
national vs. local drivers of change, 151
obstacles to communication, *251*
poverty, 57
rainforest ecosystem and, 45
time frame for, 178
unsustainable trade-offs, 195
wildlife management areas, 212, *213*
Paradigm, defined, 89
Participation of local stakeholders. *See* Stakeholders in sub-global assessments
Peer review of assessment findings, 136
People's Biodiversity Register, 80, 106, 264
Philippines. *See* Laguna Lake Basin assessment (Philippines)
Physical drivers, 150–151
Pollution, **5,** 143. *See also* Air pollution; Water resources
Population growth. *See* Demographic drivers
Portugal assessment, *304, 345,* 345–346
afforestation policy and reduction of pastoral land, **9**
biodiversity trends, 185, 253
climate-related extreme events, 150, 163
conceptual baseline, 177
condition and trends of ecosystem services, *178,* 179
description of, 69
drivers' changing nature, 75–76, 165
economic valuation of forestry sector, *177*
educational activities, 194
EU policies and local decision-making, **5,** 69, 165, 166, 218, 253
food provisioning, 58
human well-being and, *49,* 51, 272
interdisciplinary integration, 104
invasive species, 182
irreplaceable biodiversity, 184, *294*
local people working in agricultural terraces, *274*
MA conceptual framework and, 124
market system, 158
nested, multiscale design of assessment, **9,** 69, *72*
recreation services, 193
reporting categories, 199
scenario-building, **7,** 240, 245, 253, 254
social services and, 54
time frame of, 177
Post normal science, 90

Poverty
destructive, 57
ecosystem degradation and, 17, 182
equal reliance on ecosystems, **3**
global political order and, 82
human well-being and, 22–23, 47, 272
reliance of the poor on ecosystems, **4**
unequal access to ecosystem services, 22
Provisioning services, 52–53, 188–190
availability of data for assessment, 180
biological products, 53
condition and trends, 189–190, *202–203*
defined, 19
drinking water, 52
drivers of change for, 188
indicators of condition and trends, 188–189
trade-offs with regulating services, 195
woodfuel. *See* Fuelwood

Q

Qualitative assessment of condition and trends of ecosystem services, *178, 202–203*
Quecha. *See* Vilcanota assessment (Peru)

R

Ramsar Convention on Wetlands, 16
Recreation, 54, 182, 191. *See also* Tourism
Reef Condition Index, 184
Regional factors
affecting local communities, **9**
as drivers of change, **6,** 143, 152, *155*
Regulating services, 53–54, 190–191
availability of data for assessment, 180
condition and trends, 191, *202–203*
indicators of, 190–191
defined, 19
drivers of change for, 190
infectious diseases, 54
trade-offs with provisioning services, 195
water flow, 53–54
Remote sensing, 174
Research institutions and response options, 207
Resilience, 109, 167–168, 209, *210,* 265, 275
Responses to ecosystem change, 205–228, 286–287
actors' role, 220–221
categories of actors, 208
complexity of sub-global responses and, 211
in future assessments, 220–221
assessment of, 208–211
institutions and, 209
resilience of social-ecological systems, 209, *210*
response features, complexity, and choices, 208–209, *209*
complexity of sub-global responses, 211–213, *215*
diversity enhancing effectiveness of options, **8,** 207
drivers of change and, 135, 166, 207
dynamic nature of, 214
effectiveness of multilevel responses, 214–215
findings on, 211–215
innovative institutional response mechanisms, 80
instruments of action, 208, 213
knowledge systems and, 208, 212–213
lessons learned from, 215–220
collaboration, 215–218. *See also* Collaboration
economic and social incentives, 218–219
for future assessments, 220–221
national legislation and, *215*
organizational levels in response, 211–212
public and private sector actions, *213*
selection of responses and methods for assessing effectiveness, **6–7,** 209–211, *222–226*
spatial reach and effectiveness of, 213–214, 219–220, 221
stakeholders' effectiveness and, **7,** 207–208
synergy and coherence, **7,** 207, 220
unexpected results, *213*
Risk assessment, 26–27
Russia. *See* Altai-Sayan Ecoregion
Rwanda, 58

S

Sacred groves and pools, **3,** 81, 107, *193,* 272–273
SAfMA Gariep assessment, *306, 349,* 349–350. *See also* Southern African Regional assessment (SAfMA Regional)
aligning assessment and management scales, 74
biodiversity condition and trends, 186
conservation targets, gap assessments, and conservation status, *185*
cultural importance of ecosystem services, *193*
educational activities, *268*
human well-being and, *49*
information from Gariep Basin not equally included in assessment, 75
participation of local stakeholders in ranking ecosystem services, 176, *176*
user group involvement, *131*
PODIUM model, 176, 196
relevance to local needs, 76
supply-demand approach, 177, *179*
trade-offs, evaluation of, 196
water resources, 189
San Pedro de Atacama assessment (Chile), *298, 316,* 316–317
advisory committee, **14,** 99, 107, 128, *213,* 217
technical team interaction with, *132*
community engagement, methods of, *267*
educational activities, *268*
exchange with Western China assessment, *138*
human well-being, view of, 272
lifestyle changes, 150, 159
MA conceptual framework and, 109
mining's effect, ***5,*** 52, 162
public and private sector actions, *213*
scenario-building, **7,** 251
sense of place and identity, **8**
tourism, 162, 194
traditional knowledge, 106, 110, 111, 212–213, 264
scientific knowledge vs., 102
traditional medicine, 96
user groups at exploratory stage, 126
water shortage, 52, 124, 189
scenario's focus on, 254
trade-offs and local community involvement, 77
São Paulo Greenbelt assessment (Brazil), 362
aggregated response, *215*
educational activities, 194
partial control of drivers at local level, 151, 214
unsustainable extraction of natural resources, 160
urbanization, 162
water resources, **5**
Saudi Arabia (Assis National Park), 338
Scale. *See* Cross-scale interactions; Multiscale assessments; Spatial scales
Scenario-building, 135–136, 229–259, 284
Adapting Mosaic scenario, 257–258
assessing work in progress, 234
benefits of, 77, 231
biodiversity and, 253, *253*
challenges in sub-global assessments, 135, *135*
communication in, **7,** 250–252, *251*
cross-scale processes in, 245–247
definition of scenario, 232
design and implementation, *235*
development process, 239–244, *240, 242*
diversity of approaches, 239
frameworks to develop storylines, 239–242, 251–252
quantification and spatial explicitness, 242–244, *244*
systems models in, 242–244, *243*
differences from global assessments, 231
ecological surprise, consideration of, 245
findings of, 252–255
commonality of, 252–254
comparing across scales, *254,* 254–255
Global Orchestration scenario, 257
identification of winners and losers, 231
incorporating ecology into, 244–245
integrating with other assessment components, 256
key ecosystem services addressed in, *253,* 253–254
lessons learned, 136, 231, 255–257, 284
in MA global assessment, 232, 257–258
multiscale processes in, 245–247
Order from Strength scenario, 257
participation in, 248–250, *249*
in policy dialogues, 250
purpose of, **7,** 26, 231, 232, 234, 284
qualitative models used in, 231
scale issues, 245–248
differences of findings across scales, 254–255
reasons for including or excluding multiscale considerations, *245*
spatial extents, heterogeneity, and resolution, 247
temporal scale, 247
spatial mapping or modeling, 252
stakeholders, importance for, **7,** 255
sub-global vs. global, **7,** 232–234, 247–248, 256
summary of in sub-global assessments, 232, *233–234,* 234
TechnoGarden scenario, 258
theatrical performance or film and video recording to represent, 252
uncertainties as focus of, 231, 236–239
cascading uncertainties in social-ecological systems, 238, *239*

description of uncertainties, 238
findings, 253
global vs. sub-global, 68
identification of key uncertainties, 236, 238, 253
major uncertainties across sub-global scenarios, *237*
relationship of uncertainty to ecosystem services, 238–239
technology as substitute for ecosystem services, 77
water resources and, 254
Science, as knowledge system, 89–90
afforestation, 195
assessment vs. research, 282
integration of local/traditional knowledge with, 92, 107, 264
local/traditional knowledge vs., 102, 107, 108
watershed management, 195
Science and technology drivers, 149–150
Security and human well-being, 22, *49, 50*
Sense of place
ecosystems providing for local people, **8,** 51
local knowledge and. *See* Knowledge systems
Sinai assessment (Egypt), 327, 338
cropping system, 96
global and national ''trickle-down'' to local level, *158*
grazing, 55
invasive species, 93, 96
local/traditional knowledge, 108, 110
scenario-building, *245*
tourism, 162
Single-scale assessments, 66, 72, 285
Social issues
changes affecting social norms, 218–219
human well-being and, 22
multiscale assessment's ability to consider, 75
Sociopolitical drivers of change, 148–149
public participation in decision-making, 22
Soil formation and condition, 54–55, 187, 191
Sources of information for sub-global assessments, *30*
South Africa. *See also* SAfMA Gariep assessment; Southern African Regional assessment (SAfMA Regional)
inequities of costs and benefits of ecosystem change, **4–5,** 57
local knowledge transmission and state-local interactions, *96*
policy windows, role of, *211*
rural communities' reliance on ecosystem resources, **4**
Southern African Regional assessment (SAfMA Regional), *305, 347,* 347–348. *See also* SAfMA Gariep assessment
advisory committee, 126, 130–131, *131*
biodiversity conditions, ***5,*** *81,* 274
climate change as driver of change, 77
communication partnership with media, 139
conservation policies, national and international, 274
cross-scale interactions, 285
deforestation, 179
food shortages, 75, 76
governance structure as key uncertainty, 77
IMAGE model, 176, 243–244, *244*
invasive species, 182
land use change, ***8,*** 176
cultivated land, *181*
local knowledge as component of, 93, 101, 106, 107, 109, 111, 264
MA conceptual framework and multiple scales in, 73, *73,* 108, 124
nested, multiscale design of assessment, **2, 9,** 65, 68, 69, *72,* 75, 140
scenario-building, **7,** 240–242, *241,* 245, *245,* 254, 255
social networks, role of, 275
sociopolitical drivers, 148
supply–demand assessment of food and water provisioning, 177, *179*
time constraints, effect of, 114
tourism, 162–163, 192–194, *193*
''trans-disciplinary'' approach of, 104
trust among local people, 275
user group involvement, *131*
Spatial scales. *See also* Cross-scale interactions; Multiscale assessments
driver classification and, **6,** 146, 151–155
heterogeneity. *See* Heterogeneity
MA conceptual framework and, 280, 285
responses and. *See* Responses to ecosystem change
social and ecological change, 66
Spiritual and cultural services. *See* Cultural services
Stakeholders in sub-global assessments, 30–31
active user engagement, 79–80. *See also* Local communities
benefits of, 289
on-going, 136–137
advisory committees, **14,** 99, 107, 126, 128, 130–131, *131*
diversity of, **2, 10,** 72
importance of, 18
multiscale approach's focus on, 75, 77–78
participation of local stakeholders, **10, 14,** 22, 32
at exploratory stages, 124–125, *125*
techniques of, 176, *176*
scenario-building and, 248–250, *249,* 255
selection of, 74
user fatigue during assessment, 126
user groups, establishment of, 129, *130*
users vs. stakeholders, 282
Stockholm Urban (Sweden SU assessment), *308, 353,* 353–354
aggregated response to develop and maintain park, *215*
competition, effect of, 149
educational activities, 194
involvement of stakeholders from different scales, 72
parks, importance of, **3, *4,*** 54
recreation for urban residents, ***4,*** 54
scenario-building, *245*
trade-offs between ecosystem services and human well-being, **3**
urban sprawl, **6,** 162
Stockholm's National Urban Park. *See* Stockholm Urban (Sweden SU assessment)
Sub-global assessments, 119–140. *See also specific assessment by name*
adaptation of generic assessment process, 123–124. *See also* Adaptation of MA conceptual framework across scales
advisory committees. *See* Stakeholders in sub-global assessments
approved and associated assessments, 33–34, *34–41*
bottom-up approach, 32–33, 68, 139, *212,* 281
capacity-building. *See* Capacity-building activities
challenges and constraints faced by, **13,** 121, 176–182, 280, 281
condition and trends. *See* Condition and trends of ecosystem services
design of, 32–34
diversity of ecosystems in, **2, *3,*** 256
dynamic and iterative process, **12,** 121, 284
ecosystem coverage, 34–35
embedded in political, social, and environmental circumstances, **12–13**
exchanges program, *138*
exploratory stages, 124–127, *292*
funding for, 33, 126–127, *128*
geographical coverage, 34
governance-related challenges, 132–133
implementation of workplan, 133–136, *292*
initial approach, 32, 124–127, *125*
boundary conditions and limitations, 125–126
exploring potential need, scope, and users, 124–125
initiation and design stages, 127–133
establishing demand for assessment, 127–129
establishing formal governance structure, 129–133, *131*
establishing formal user group, 129, *130*
institutions involved in technical work, 132, *132*
integrated nature of, **2,** 30
knowledge systems and. *See* Knowledge systems
lack of data found for, 180–181
lessons learned from, 139–140, 279–289
locations of, *291*
overview of, **2,** 29–41, 122–123, 311–365
partnerships and exchanges program, *138*
peer review of findings, 136
pilot assessments, 124
purpose of, **2,** 80–82
requirements for success of, **12–13**
scope of, **2**
selection criteria, 32–33, *34*
stages of, ***13,*** *292*
stakeholders. *See* Stakeholders in sub-global assessments
teams as leaders of, 282
technical teams, 131–132, *132*
temporal fluctuations, 179–180
uncertainty, expressing, 181
user engagement, 121, 130–131, *131,* 136–137. *See also* Stakeholders in sub-global assessments
user groups, establishment of, 129, *130*
Sub-national scale and drivers of change, 151, *153*
Substitutions, feasibility of, 22, 287
technology as substitute for ecosystem services, 77, 150

Sulfur dioxide emissions. *See* Air pollution
Supply-demand approach, 177, *179,* 189
Supporting services, 54–55, 187–188
  availability of data for assessment, 180
  condition and trends, 187–188, *202–203*
    indicators of, 187
  drivers of change for, 187
  grazing, 55
  pollination, 55
  soil formation, 54–55
Sustainability and the future, 17, 22, 264
Sweden. *See* Kristianstad Wetlands (Sweden KW assessment); Stockholm Urban (Sweden SU assessment)
Synergy and coherence, **7,** 207, 220
Synthesis of assessment approaches for ecosystem services, 198–200

T

Technical teams, 131–132, *132*
TechnoGarden scenario, 258
Technology. *See also* Science and technology drivers
  adaptation drivers, 188
  as substitute for ecosystem services, 77, 150
  MA conceptual framework and, 220
Temperature change. *See* Climate change
Temporal issues. *See also* Drivers of change; Time scale of assessments
  fluctuations in condition and trends, 179–180
  lack of data, 177
  MA conceptual framework and, 285
  responses to ecosystem changes, 219–220
  scenario-building and, 114, *135,* 247
  scheduling of global assessments after sub-global assessments, 289
  social and ecological change, 66
  varied time frames for assessments, 177–178
Threats and insecurity
  food insecurity. *See* Food production
  overestimated at global level and underestimated at sub-global level, **8,** 186, 207
  trade-offs, 80
Time scale of assessments, 24, 69
Top-down collaboration, 68, 139, *212*
Tourism. *See also* Ecotourism
  as driver of change, 148, 162–163, *163,* 182, 191–194
  availability of data for assessment, 180
Trade. *See* Markets and trade
Trade assessment, 363
Trade-offs
  between assessment scale and management scale, 75
  between ecosystem services, **3,** 55, 173, 194–197, 199
  between ecosystem services and human well-being, **3,** 55–57, *56,* 77
  between user needs, timeline, and assessment workplans, 132
  food production, 80
  frameworks and decision-making tools to analyze, 195–198
  for future consideration, **14,** 173
  lessons learned, 287
  threats and insecurity, 80
Traditional knowledge. *See* Knowledge systems
Traditional medicine, 96, 263
Trinidad (Northern Range assessment), *307, 355,* 355–356
  biodiversity assessment, 183
  crisis management, *167*
  environment and resource education, 139
  exploitation of natural resources, 182
  green mussel from trade ships, **5**
  human well-being and, *49*
  inequitable division of wealth, 182
  market system, 158
  water flow regulation, 53
  water quality, 189
  weather patterns as indirect driver of change, 153
Tropical Forest Margins assessment, 330–331
  alternative to temporal baseline, 177
  ASB matrix and program, 197, *198,* 217
  change in scale of analysis, 75
  climate change, 150
  communication tailored to decision-makers, 251
  disagreement over focus of, 133
  drivers of deforestation, **6,** 76, 159
  food services, 190
  funding, 126
  heterogeneity, 179
  infrastructure development, 161
  integration of multiple knowledge systems, 104
  land use change, **5–6,** 166
  modeling
    CENTURY model, 175
    soft-models, use of, *243*
  nutrient cycling service, 187
  participation across multiple groups with conflicting interests, 102, 113
  scenario-building, 240
  stakeholder engagement, 97

U

Uncertainty
  as driver of human actions, 82
  dealing with through scientific and local knowledge, 267
  expressing, 181
  governance as, 77, 253
  scenarios and. *See* Scenario-building
Urban growth and urbanization
  as demographic driver, **5,** 148, 161–162, *162*
  human well-being and, 56
  parks, importance of, **3,** ***4,*** 54. *See also* Stockholm Urban (Sweden SU assessment)
User ownership, 32, 68, 77–78. *See also* Stakeholders in sub-global assessments
Utilitarian value paradigm, 24–25

V

Value associated with ecosystem services, 24–25, *25,* 176, *177,* 218
Viet Nam. *See* Downstream Mekong River Wetlands assessment (Viet Nam)
Vilcanota assessment (Peru), *308, 357,* 357–358
  adapting MA conceptual framework for local needs, ***12,*** *110,* 270
  capacity-building for conducting technical work, *134*
  collaborative participation of stakeholders, 98, 99, 100, 126
  community engagement, methods of, *267*
  cultural and spiritual values, **8,** 107
  ecosystem diversity as benefit, 271
  exchange with Bajo Chirripó assessment, *138*
  local knowledge as component of, 93, 106, 107, 108, 110, 114
  locally led assessment, 285
  MA conceptual framework and, 109
Voices of the Poor (Narayan), 47

W

Water resources
  dams, effect of, 145, 148
  fresh water, 52
  local knowledge and, 93, 96
  pollution, 182, 191
  provisioning, 189
    biodiversity, congruence of, 173
  regulation of, 53–54
  scarcity
    confirmed in smaller scale assessments, 76
    global vs. sub-global level, ***6,*** 189, *296*
  scenario-building and, 254
  trade-off with food production, 196
Western China assessment, *309, 360,* 360–361
  Agroecological Zoning model, 175
  deforestation, 190, *192*
  exchange with San Pedro de Atacama, *138*
  exploitation of natural resources, 182
  flood control and decreasing sediment, 190, *192*
  funding, 127
  MA conceptual framework and, 109, 124
  modeling used in, *74,* 175, 243
  policy windows, role of, 211–212
  regulating local activities and constraining local knowledge, 166
  responses through integrated government policy, 211–212
  scale in, *65,* 69, 72
  scenario-building, *245*
  supporting ecosystem services, *187,* 187–188
  water quality and quantity, ***9,*** 273
Wildlife management areas in Papua New Guinea, *213*
Wisconsin (Northern Highlands Lake District assessment), *310, 364,* 364–365
  key uncertainties, 236, *238,* 238–239
  MA conceptual framework and, 109
  scenario-building, **7,** *111,* 244, 245, 249
Wood fuel. *See* Fuelwood
Working for Water, 151

Z

Zambia, ***4,*** 53

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